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Conservation of Rainforests in India

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वहाँ है खुशहाली ।।

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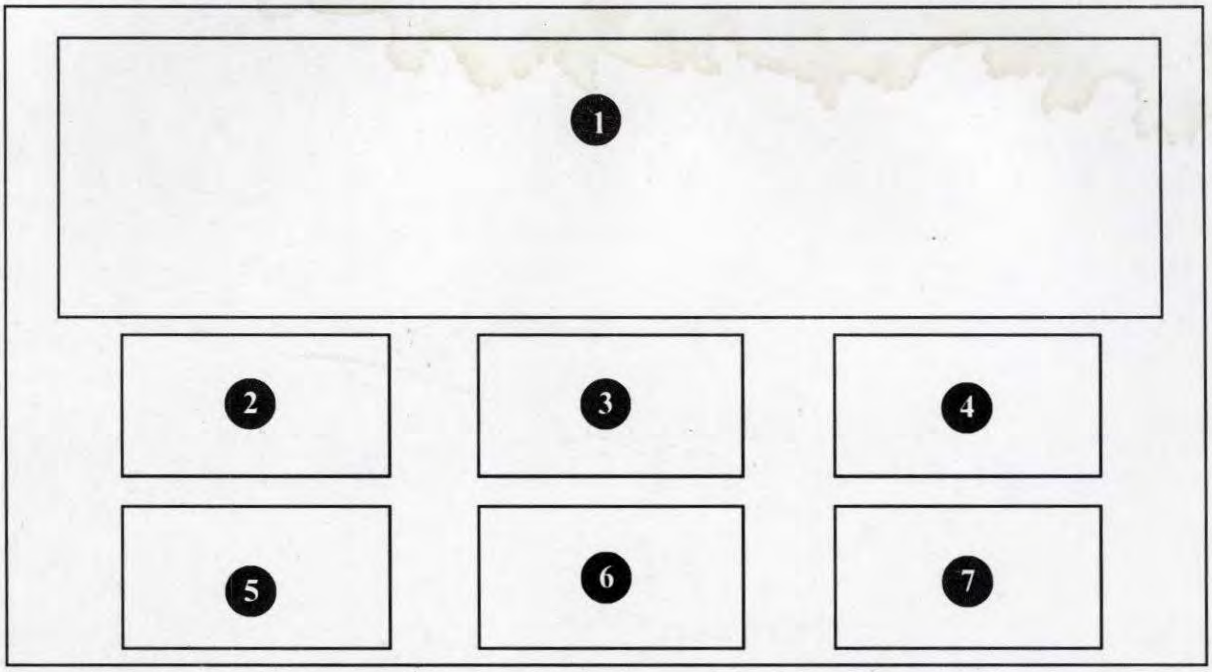

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The Environment Information System (ENVIS) Centre at Widlife Institute of India, set up in September 1997, is part of the ENVIS set-up of the Ministry of Environment and Forests, Government of India. It deals with general matters concerning "wildlife" and specifically those related to "protected areas". Its objectives are to :

* Establish a data bank on information related to wildlife and wildlife protected areas, and thereby build up a repository and dissemination centre for information on wildlife science;

* Promote national and international cooperation, and exchange of wildlife related information;

* Provide decision makers at the apex level with information related to conservation and development.

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Mailbag

Congratulations for bringing out a useful publication on the least known and least studied animals of the remote areas.

Professor V.C. Soni
Saurashtra University
Rajkot

Congratulations to WII-ENVIS centre for the excellent documentation in the 'Mountain Ungulates' issue.

Avenash Dutta
Consultant
Indo-Canadian Shastri Institute
New Delhi

The issue contains interesting as well as useful information.

Dr. Sukumar Deweta
Director
NEERI, Nagpur

While there are large numbers of books on the fauna inhabiting the plains of India, not much documentation is there with respect to mountain fauna. This issue will bridge the gap of documentation on wildlife conservation in the Himalayas

S.C. Dey
Secretary General
Global Tiger Forum
New Delhi

The issue is a very welcome addition in our library.

Dr. Manickam, Dean
Tamil Nadu Veterinary and Animal Sciences University, Namakkal, Tamil Nadu.

This issue contains mammoth information on all ungulates species occuring in the Himalayan and Trans-himalayan biogeographic zones of India.

Prof. C.K. Pandey
Sulabh International
Social Service Organization, Patna

This issue is a valuable addition to our small but fast growing library and a source of information for our numerous members.

Anil Kumar V. Epur, Chairman
WWF-Andhra Pradesh State Committee,Hyderabad

The staff and students of the Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP) will be greatly benefited with this publication.

Dr. Karl Harmsen
Director,
CSSTEAP, Dehradun

Director's Note

The rainforests in India are the centre of species richness and endemism and provide the country a proud status of being one of the 12 mega-biodiversity countries in the world. Even the two hotspots in India, the Western Ghats and the Eastern Himalayas, owe their status due to the presence of rainforests therein. These forests form very important catchments areas for major river systems, maintain soil and water fertility not only in the immediate vicinity but also hundreds of kilometers away, harbours rich indigenous culture with long traditions of sustainable use of traditional knowledge systems especially on medicines and wild relatives of cultivate crops. It is to these rainforests that more than 80% of the endemic flora and fauna of India are confined. Being the most complex ecosystem, the rain forests are living laboratories in which complex ecological, biological and evolutionary processes that have shaped the Earth can be studied.

However, in spite of their overwhelming importance in terms of biodiversity and human welfare, rain forest have received little conservation and research attention compared to other ecosystems in India. This is in sharp contrast to major advances in our understanding of the ecology and conservation requirements achieved during the last four decades through systematic research with respect to the rain forests in Southeast Asia and South America.

In recognition of the above facts, the Wildlife Institute of India, in collaboration with the Salim Ali Centre for Ornithology and Natural History, Coimbatore, and the State Forest College, Coimbatore, organized a three day workshop on 'Research Priorities in Tropical Rain Forests in India. The Ministry of Environment and Forests, Government of India, New Delhi funded this workshop, whose main goal was to consolidate and review the research findings based on the last two decades of research in the rainforests in India, to identify and prioritize critical gaps in information that can be addressed through future research projects in these biodiversity rich ecosystem, and document and disseminate above information. The participants drawn from various institutions, universities, government departments and NGO groups, presented review papers on major (especially lesser known) taxa (herpetofauna, butterflies, other invertebrates, micro-organisms, mammals and birds), followed by working sessions in different sub-groups to systematically evaluate research on each taxa to identify information gaps and prioritize conservation and research needs
for future.

I hope that the readers will find this ENVIS issue, which is based on the output of the said workshop, highly informative in developing current understanding of the distribution and conservation status of various lesser known faunal elements, in identifying the major gaps in our knowledge on rainforests in India, and stimulating enough to be able to prioritize the taxa and areas for addressing the future research needs in this unique ecosystem.

Our next issue of ENVIS will be on 'Ungulates of Peninsular India'.

(S. Singsit)
Director, WII & Team Leader
ENVIS Centre, Wildlife Institute of India

Foreword

I am honoured to have been asked to write a Foreword to this book deriving from a Workshop held at Coimbatore in 2001. My interest in Indian forests goes back to my childhood but has flowered during the past 12 years while I have been an Editor and latterly Editor-in-Chief of the journal Biological Conservation. During these past few years I had the pleasure of receiving a number of papers covering such diverse topics as: the Gir Lion reserve in Gujarat, the ecology of Phayre's Langur, the status of Tiger and Leopard and the conservation of medicinal plants in Northeast India, and the Grizzled Giant Squirrel, the Lion-tailed Macaque, the Nilgiri Tahr and the Cochin Cane Turtle in the southern Western Ghats. These have helped to focus attention on a range of conservation issues of international interest.

The Western Ghats have a special resonance for me since I was born in Coimbatore, then a sleepy town on the edge of this important and ancient mountain chain of south and western India, when my father, P.W.Davis IFS, was Principal of the Forest Rangers' College of the then Madras Presidency. Our family accompanied him subsequently when he was D.F.O. Nilambur and D.F.O. Nilgiris and I also went to school in the Anamalais bordering the Grass Hills until 1945. Since 1996 I have returned to India four times to revisit all these places and have had the pleasure of meeting many Indian Foresters and wildlife researchers and advisors in Kerala, Tamil Nadu and at Dehra Dun to see and discuss conservation issues. I have been especially privileged to spend a day at Silent Valley in Kerala and at the Indira Ghandhi NP in the Anamalais with young researchers; and above all to have spent three days walking across the Eravikulam–Grass Hills plateau with Wildlife Wardens from Munnar, and another three days walking from the Western Catchment of the Nilgiris through Silent Valley under the guidance of the Range Officer from Ooty.

Rainforests are being depleted all over the world, the scenario in India being no exception. Nevertheless, based on my personal observations and on my reading on the subject, I know that India has been successful in conserving vast tracts of species-rich forests, and the government and the people deserve praise for this notable achievement. The saving of Silent Valley as a National Park is a case in point. It is pertinent to remember that the term Conservator goes back to the very earliest days of forestry when the Indian Forest Service was developed as a brake on unbridled exploitation by ensuring sustainability of forest products. Unfortunately, the War years 1939-45 saw serious disruption in the elaborate Working Plans that had been prepared, and enormous devastation of forest lands for the war effort, especially those outside the direct control of forest departments; one of my father's post-war jobs was to report directly to the Chief Conservator, Jal A. Master, on the Despoliation of Private Forests. The following decades were marked by further clearance of forest for agriculture and settlements; the loss of forests in Kerala alone between 1965 and 1973 has been estimated at about four thousand square kilometres. Such loss of forests led finally to the Wildlife (Protection) Act of 1972, which established a separate branch especially for wildlife conservation within the Forest Department. This Act, together with the Forest Conservation Act of 1980, established the essential role of forests as a natural resource 'to be protected and enhanced for the well-being of the people and the nation': thus they marked the modern view of conservation in which direct economic benefit is subordinate to sustaining the ecology of habitats such as the unique

rainforests of the Nilgiri Biosphere Reserve and Northeast India.

Whilst the management responsibility for forest conservation must fall upon the Forest Department, the basic science must depend upon professional biologists, such as those represented in this book. Their contributions detail a wide range of studies on both vertebrates and invertebrates in rainforests of India. As someone who has grappled with the sampling and identification of soil mites and spring-tails to study the effects of soil pesticides, recorded the feeding habits of nesting birds to study DDT food chains, and used insects to study habitat fragmentation and colonisation, I am aware of the need for much basic science to underpin applied research. This applies especially to the more "difficult" and less well studied groups such as snails, spiders and millipedes whose diversity and distribution are addressed in this book. While walking continuously through Silent Valley, I was struck by how few species of animals one normally sees in rainforest and yet how, on the other hand, an expert in arboreal mammals could demonstrate their presence to me at night, and how an ornithologist can detect the presence of forest birds from a fleeting glimpse or call. He or she must expect to spend weeks or months getting to know their calls and behaviour before they can tackle such vital questions as: What is the minimum size of forest fragment that a particular species needs to provide the food and breeding resources to sustain a population? What role do they themselves have in the food web or in perpetuating the plant community through pollination or spreading of seeds? What size of gap between two fragments acts as an insuperable barrier to dispersal? If these questions are difficult to answer for the larger and more conspicuous fauna, how much more so are they for the more obscure species such as caecilians or millipedes. This book, therefore, does a most valuable service in prompting such questions and making recommendations for future priorities in research.

The two introductory chapters to this book illustrate the incredible biological richness of the Western Ghats and Northeast India. The proportion of endemic species among some groups must compare well with any part of the world. Nevertheless, whilst some of this information goes back 200 years or more, and some derives from intensive surveys by such notable biologists as Salim Ali, we are made aware of just how ignorant we still are about some groups, such as bats in Northeast India and most invertebrates other than butterflies. The fact that several new species of amphibians and even a new species of deer can still be added to the Indian fauna in Northeast India points to the excitement that such basic surveys can bring. Many groups of organisms depend upon specialised sampling techniques and taxonomic skills just to discover what species are present, let alone to understand their complex interdependence within this rich tapestry.

Much is already known but it falls to each generation to push forward the limits of this knowledge and to ensure that as much as possible is conserved for future generations. Education in the natural sciences and in conservation is essential at all levels but even more important is a commitment at the highest levels to implement and support the results of research to ensure that India maintains its rich heritage into the future.

Brian N. K. Davis
Chief Editor
Biological Conservation

Preface

Tropical rainforests are considered to be the storehouse of Earth's biodiversity. Eighteen of the world's 25 biodiversity hotspots owe their status to tropical rainforests. The reasons for protecting these forests are many: they protect soil fertility, prevent flooding, and provide valuable timbers and a huge variety of non-timber forest produce. These forests are also veritable mines of hundreds of biological products such as medicines and other phytochemicals, which could change human life, including alleviating human poverty in the tropics. Finally, rainforests are living laboratories in which complex ecological, biological and evolutionary processes, which have shaped the Earth, can be studied.

The Western Ghats, Northeast India and the Andaman and Nicobar Islands form the main regions of tropical forests in India, especially the rainforests, and India's position as one of the 12 megadiversity countries in the world is largely due to these rainforests. Surprisingly, in spite of their overwhelming importance in terms of biodiversity and human welfare, rainforests in India have received very little conservation and research attention until recently. Protected areas in India have been, by and large, designed to conserve large mammals, which generally inhabit moist and dry deciduous forests so these habitats are much better protected than rainforests. Recognising this, the Ministry of Environment and Forests, Government of India, provided funds for a workshop the goal of which was to consolidate and review the research findings on rainforest fauna in India, and to identify and prioritise critical gaps in information which could be addressed by research in the coming years.

Accordingly, a three day workshop was held at Coimbatore, Tamil Nadu, during February 2001. It was organised by the Wildlife Institute of India, the Salim Ali Centre for Ornithology and Natural History, and the State Forest Service College, Coimbatore. It attracted eighty two participants drawn from different parts of the country, with differing scientific backgrounds and expertise on varied taxa. In addition to representatives from the organising bodies, the major participants in the workshop were the Kerala Forest Research Institute, Tropical Botanical Research Institute, Botanical Survey of India, Zoological Survey of India, Centre for Ecological Studies, State Forest Research Institute, Bombay Natural History Society, National Botanical Research Institute, Forest Survey of India and several State Forest Departments. The current volume is an outcome of the papers presented during the said workshop.

The two introductory papers on the Western Ghats and Northeast India give an overview of the biodiversity and also conservation priorities and prospects, while the rest of the papers covered in this volume, while viewed holistically, provide rare insights into the rainforest ecosystem in India. As the first two papers show, mammals and birds tend to be much better known than other groups. Many groups such as amphibians, reptiles, fishes and invertebrates have highly restricted distributions, and the invertebrate fauna of rainforests has been largely ignored due to the size of the task, ignorance of their

importance, their small size, difficulties in studying, insufficient expertise *etc.* We are therefore happy to state that the many of the papers in this book are devoted to non-charismatic and less known creatures. Though the workshop had representation by scientists from the Andaman and Nicobar group of Islands, but due to non-receipt of the written articles dealing with the rainforests in those islands, the same could not be included in this volume. Nevertheless, it is hoped that the articles in this volume show advances in our understanding of the ecology and conservation requirements of rainforests of Western Ghats and Northeast India.

It is further hoped that this volume will help stimulate further research in all the rainforests in India and more importantly on the so called less-charismatic, yet, biologically and ecologically extremely valuable species of flora and fauna contained therein.

A.K.Gupta, Ajith Kumar, V.Ramakantha

Editors

Chapter 1

BIODIVERSITY OF NORTHEAST INDIA AN OVERVIEW

V.Ramakantha, A.K.Gupta, Ajith Kumar

Introduction

The immense variety of the climatic, edaphic and altitudinal variations in India have resulted in a great range of ecological habitats for which Northeast India takes the pride of place. Lying between 22-30 degree N latitude and 89-97 degree E longitude, and sprawling over 2,62,379 sq.km., Northeast India represents the transition zone between the Indian, Indo-Malayan and Indo-Chinese biogeographic regions and a meeting place of the Himalayan Mountains and Peninsular India. It was the part of the northward migrating 'Deccan Peninsula' that first touched the Asian landmass after the break up of Gondwanaland in the early Tertiary Period. Northeast India is thus the geographical 'gateway' for much of India's flora and fauna, and as a consequence, the region is one of the richest in biological values. It is in this lowland-highland transition zone that the highest diversity of biomes or ecological communities can be found, and species diversities within these communities are also extremely high.

Northeast India is blessed with a wide range of physiography and ecoclimatic conditions. The State of Assam has extensive flood plains, while Khangchendzonga in Sikkim stands 8586 m. tall. Cherrapunjee in the State of Meghalaya holds the record for the highest rainfall in a single month (9,300 mm) as well as the most in a year (26,461 mm) in India, while the nearby Mawsynram has the world's highest average rainfall (11,873 mm). The forests in the region are extremely diverse in structure and composition and combine tropical and temperate forest types, alpine meadows and cold deserts. There are regions, for example, in the State of Sikkim, where the faunal assemblages also change rapidly from tropical to subtropical, temperate, alpine and finally to cold desert forms.

After the Andaman and Nicobar Islands and the Western Ghats, Northeast India forms the main region of tropical forests in India, especially the species-rich tropical rain forests. The tropical semi-evergreen and moist deciduous forests in the lowlands of this region extend south and west into the subcontinent, and east into Southern China and Southeast Asia. The subtropical forests of the region follow the foothills of the Himalaya to the west; also extend into Southeast China in the east. Himalayan temperate and subalpine zone forests extend from northern Pakistan and adjacent Afghanistan through Northeast India to Southwest China. Each of the eight States of the region, namely Arunachal Pradesh, Assam, Meghalaya, Manipur, Mizoram, Nagaland, Sikkim and Tripura, boast of several endemics in flora as well as fauna. This region represents an important part of the Indo-Myanmar biodiversity hotspot, one of the 25 global biodiversity hotspots recognized currently.

Flora

The vegetation of the northeastern region is fairly well known. With about 1,67,000 sq.km. area under forest, this region accounts for approximately 7500 species of angiosperms. The State of Sikkim alone holds about 5000 species of flowering plants.

Out of 315 families of Angiosperms in India, more than 200 are represented in Northeast India and this region accounts for nearly 50% of the total number of plant species in India as a whole. Though the flora of this region exhibits an Indo-Malayan affinity, the floral elements of other parts of India, and of neighbouring and far off countries, have also contributed to its richness and diversity. It is of interest to note that about one third of the flora of Northeast India is endemic to this region.

The striking feature of the flora of Northeast India is the presence of many primitive flowering plants eg. *Magnolia pealiana, M. qustavii, Tetracentron sinense, Holboellia latifolia, Exbuchlandia populnea, Manglietia sp., Myrica esculenta* and *Corylopsis himalayana.* The Coriariaceae, Nepenthaceae, Turneraceae, Illiciaceae, Ruppiaceae, Siphonodontaceae and Tetracentraceae are monogeneric families represented in this region. Furthermore, some of the important gene pools of citrus, banana, mango and rice are reported to have originated from this region. Of these, mango and banana show the maximum diversity in this region. The carnivorous Pitcher Plant (*Nepenthes khasiana*) is endemic to Meghalaya and is listed in Appendix I of CITES and placed in Schedule VI of the Wildlife (Protection) Act, 1972. Siroy Lily (*Lilium mackliniae*), a ground lily that produces beautiful flowers, is a narrow endemic found in the eastern border area of Manipur.

The tropical forests found in the Indo-Myanmar border areas have many representative species in the Indian context, such as - *Dipterocarpus tuberculatus, D. turbinatus* and *Melanorrhea usitata* to name only a few. Similarly, Sikkim Himalayan region is a wonderland as Sino-Japanese floristic elements (eg. species of *Quercus, Schima*), Western China elements (eg. *Aletris pauciflora, Anemone rupicola, Magnolia campbelli*), Tibetan elements (eg. *Hippophae, Prezwalskia*), Siberian elements (eg. *Potentilla, Pedicularis*) and other floristic elements from near and far-off lands have a significant presence in the region. In addition to this, there are very interesting areas in the region that are termed as 'Isolation belts' that have led to the isolation of certain species. *Meconopsis bella, Cathcartia lyrata, Senecio chola, Sausrea laneana, Geranium spp., Primula elwesiana, P. wattii* and *Swertia burkilliana* serve such examples in the Sikkim Himalaya.

Orchids, believed to have evolved in this region, form a very noticeable feature of the vegetation here. Of about 1300 species of orchids, belonging to 158 genera reported from India, Northeast India sustains the highest concentration with about 700 species. As many as 34 species of orchids from Northeast India are listed among the threatened plants of India. The following are some ornamental orchids of the region: *Paphiopedilum fairieanum, P. insigne, P. villosum, P. spicerianum, P. hirsutissimum, P. venestum, Anoectochilus sikkimensis, Vanda coerulea, Vanda teres, Renanthera imschootiana, Pleione maculata, Cymbidium eburneum, Dendrobium hookerianum, D. densiflorum, D. devonianum, D. thyrsiflorum* and *Thunia marshalliana.* There are 550 species of orchids in Arunachal Pradesh alone – the highest number in any State (Of these, 350 are epiphytes, 160 are autophytic terrestrials, and about 20 are saprophytes). Many

species of orchids are of medicinal importance. For example, the fresh as well as dried stem of the orchid *Dendrobium nobile* is used in the preparation of the Chinese drug 'Shih-hu', used as an aphrodisiac, analgesic and for longivity.

The Sikkim Himalaya harbours as many as 190 wild plants that are suitable for human consumption. In the State of Tripura, [parts of] more than 60 such species are used as vegetables. In Manipur more than 430 species are being used for medicinal purposes. In parts of Assam and Manipur, the tree *Parkia roxburghii* yields good timber and also provides edible flowers and pods that are highly prized. Agarwood (*Aquillaria malaccensis*) that occurs in the tropical forests of the Northeastern region is highly prized and is listed in Appendix II of CITES Schedule VI of the Wildlife (Protection) Act, 1972.

Rhododendrons are known for their showy flowers and foliage. Out of 82 species of rhododendrons recorded from Himalaya, 70 species are confined to eastern Himalaya. Hooker's expedition to Sikkim in 1848 revealed 45 new species, which included the yellow flowered *Rhododendron campylocarpum* and *R. wighti*; the red-flowered *R. thomsoni*, the small tree *R. falconeri* and the large *R. griffithianum* with massive white flowers. However, unfortunately, nearly half of the Rhododendron species have become rare and threatened and some of the very ornamental species are now facing extinction eg. *Rhododendron nuttalli, R. falconeri, R. edgeworthii, R. elliotii, R. hookeri, R. macabeanum* and *R. watti.*

Hedychiums of the family Zingiberaceae make excellent ornamental plants and the following are rare and threatened ornamental species of this group: *Hedychium luteum, H. aureum, H. radiatum, H. robustum, H. dekianum.*

Out of 136 species of bamboos found in India, 63 species in 22 genera are found in Northeast India, spread over an area of 30,500 sq.km. Distribution patterns of bamboos in the region reveal that the species of *Bambusa, Dendrocalamus, Dinochloa, Cephalostachyum* and *Neohouzeoua* are mostly confined to the lower altitude ranging between sea level and 600 m. ASL. Species of *Arundinaria, Chimonobambusa, Semiarundinaria, Sinobambusa, Thamnocalamus* and *Phyllostachys* are found in altitudes between 800 and 3500 m. The largest contribution to the growing stock is from *Dendrocalamus strictus* (45%), followed by *Melocanna baccifera* (20%), *Bambusa bambos* (13%), *D.hamiltonii* (7%) and *B. tulda* (5%), with the rest sharing 6%. About 25 species of bamboo are considered rare in Northeast India.

In Northeast India, 28 species of conifers are recorded. *Pinus kesia* is mentionworthy as it could be seen growing in pure patches at elevations of 900 to 1800 m. and it is one of the fast growing trees of this region. *Cycas pectinata* is a rare gymnosperm that occurs in Kamrup and *Gnetum gnemon* occurs in Khasi, Jaintia and the Naga hills. *Podocarpus nerifolia,* a broad-leaved gymnosperm is reported from the Khasi hills, but also occurs in the tropical forests of Barak Valley in Manipur State and in Assam.

Northeast India is also known for a variety of saprophytic plants like *Monoropa uniflora, Epipogeum roseum, Aeginitia indica* and the giant orchid *Galeola falconeri.* The largest root parasite, *Sapria himalayana* is a rare species of the region which produces large (about 35 cm. in diameter) crimson flowers. Similarly, *Belanophora dioica, Mitrastemon yamamotai* (a polyendemic), *Boschniackia himalaica, Epipogeum roseum, Euryale ferox etc* are botanical curiosities of the region.

Northeast India also has a high diversity of non-flowering plants. Of about 1000 species of ferns found in India, nearly half are represented in Northeastern India. *Dipteris wallichii, Asplenium nidus, Osmunda cinnamomea, O. claytoniana, O.regalis, Helminthostachys zeylanica, Botrychium lanuginosum, Angiopteris evecta, Cyathea gigantea, C. spinulosa, Psilotum nudum, Phagopteres auriculata etc,* are some of the rare and interesting non-flowering vascular plants. Of these, *Platycerium wallichii* (Staghorn Fern) from Manipur appears to be the first report of its occurrence within India. This epiphytic fern grows in the moist deciduous forests in the Indo-Myanmar border areas in great profusion. Fern-allies such as *Lycopodium* and *Selaginella* are also diverse in this region.

The region is exceedingly rich in lichens, mosses and liverworts. These seemingly unimportant plants need to be investigated, studied, appreciated and above all, protected, as they serve vital ecological roles as soil protectors; contribute to the recycling of nutrients and water, offer food and shelter to an assemblage of invertebrates and take a part in air purification and carbon sequestration.

Fauna

Mammals

There is a paucity of exploration and research concerning the fauna of Northeast India. Mammals are often considered the best-known groups, especially the ungulates. However, a new species of barking deer, 'Leaf Deer (*Muntiacus putaoensis*), which was recently discovered in Myanmar, is reported from the forests of Arunachal Pradesh in the year 2003 as a new record for India, and this amply justifies the above observation that much is yet to be identified, named and studied in Northeast India. The remoteness of the region, difficult terrain as well as the severe hunting pressures exerted by the people around their immediate surroundings in many parts of the region make it extremely difficult to document the fauna of the region.

Primates

Northeast India sustains eleven species of primates, if we follow the recent revisions in primate taxonomy. It is but unfortunate that except three species, which could be considered common in Assam, they face an uncertain future in this region.

The Hoolock (*Bunopithecus hoolock*) is the only ape in India. The eastern limit for this lesser ape is Salween River in Myanmar and its range extends to Southern China. it

occurs in Assam, Arunachal Pradesh, Manipur, Meghalaya, Tripura and Mizoram in Northeast India, and its continued existence in the State of Nagaland is uncertain. Despite the wide area in which the animal occurs, it has become a rare animal, all over its range. Monogamy, frugivory and adaptation to brachiation make the species highly susceptible to habitat fragmentation and degradation. Most of the tropical forests that harbour this species are subjected to slash and burn or shifting cultivation and therefore, the ape's habitat is highly degraded and fragmented. It is hunted for the pot and the belief that its flesh and blood have medicinal properties has made it a highly prized commodity. It is also highly prized in the pet trade. All these are detrimental to the survival of the species.

The Golden Langur (*Trachypithecus geei*) is one of the most localized species, between Manas and Sankosh Rivers in the Himalayan foothills along the Assam - Bhutan border areas. This narrow endemic was discovered in Chakrashilla Hills Reserve in the Dhubri District of Assam, and the area has been turned into a wildlife sanctuary. This Schedule I animal is listed in the Appendix I of CITES.

Within 5.8 % of the state's protected area in Tripura, one can count seven species of primates. The Phayeri's Langur (*Trachypithecus phayeri*) assumes high conservation significance, as this species is restricted in distribution to the State with reported existence of a few troops in North Cachar Hills of Assam, adjacent to the northern boundary of Tripura. Yet another species of particular interest is the newly designated primate species, *Semnopethicus schistaceus* (Nepal Langur), which is endemic to the higher elevations in Sikkim and Nepal. The Capped Langur (*Trachypithecus pileatus*) is also a rare animal with limited distribution in Northeast India.

The Stump-tailed Macaque (*Macaca arctoides*) and the Northern Pigtailed Macaque (*M. leonina*) have sympatric distributions in Northeast India and both have become endangered. The Slow Loris (*Nycticebus bengalensis*) is an inhabitant of tropical forests south of the Brahmaputra River in Northeast India. This highly endangered animal is listed as Schedule I animal, and in Appendix I of the CITES.

Carnivores

If India has the distinction of harbouring six largest cats of the world, the State of Arunachal Pradesh prides itself for sustaining four large cats of Asia – the Tiger (*Panthera tigris*), Leopard (*Panthera pardus*), Snow Leopard (*Uncia uncia*) and the Clouded Leopard (*Neofelis nebulosa*). Of these, the Indian population of the Clouded Leopard is restricted to the Northeastern region. With a very long tail for balance and large paws for climbing, the Clouded Leopard is well suited for life in the canopy. It also has the longest upper canines proportional to its skull size of any cat, reminiscent of the saber-toothed cat. Despite the presence of this elusive animal in all the eight states of the region, its habitat is shrinking at an alarming rate. Vast tracts of forests, especially in the State of Arunachal Pradesh, where the animal reigns free, could remain safe for this magnificent animal, provided such forests are kept away from

developmental activities, including the construction of roads.

Tiger has become a very rare animal in the entire region and perhaps Assam provides the safest asylum for this large cat. There is a reliable report of this magnificent animal (a tigress with a cub) appearing in the forests of Tripura, after an absence of almost 25 years! The more adaptable Leopard has managed to survive in greater numbers. Little is known about the status of Snow Leopard, which ekes out a living in the high altitudinal zones of Arunachal Pradesh and Sikkim.

Northeast India sustains diverse assemblages of small carnivores, and this region is perhaps the richest region for small carnivores in the entire planet. The tiny State of Manipur, with an area of 22327 sq.km., apart from sustaining three large cats, harbours the Marbled Cat (*Pardofelis marmorata*), Golden Cat (*Catopuma temmincki*), Leopard Cat (*Prionailurus bengalensis*), Fishing Cat (*Prionailurus viverrinus*) and the Jungle Cat (*Felis chaus*). It also has 3 Mustelids and 7 Viverrids: Yellow-throated Marten (*Martes flavigula*), Ferret Badger (*Melogale* sp.), Hog badger (*Arctonyx collaris*), Eurasian Otter (*Lutra lutra*); and among the Viverrids, Small Indian Civet (*Viverricula indica*), Large Indian Civet (*Viverra zibetha*), Common Palm Civet (*Paradoxurus hermaphroditus*), Himalayan Palm Civet (*Paguma larvata*), Binturong (*Arctictis binturong*) and Spotted Linshang (*Prionodon pardicolor*). Two other species of Otter, namely Smooth-coated Otter (*Lutrogale perspicillata*) and Small-clawed Otter (*Amblonyx cinereus*), known from elsewhere in India, may also occur in Manipur State, while Arunachal Pradesh and Sikkim, may have even more species of small carnivores than Manipur.

The mind-boggling assemblage of small carnivores and other biota in the Northeastern States could be attributed to the wide ranging altitudinal variations that one comes across in the region and also to the heavy rainfall and humidity that triggers luxurious plant growth especially in the lower elevations. It needs to be emphasized that all these rare animals occupy narrow bands of forests in the hills and valleys of the region, and, living in small populations, they are extremely susceptible to habitat degradation and hunting pressures. Many of the species in lowland forests are already on the brink of extinction as these forests were the first to be occupied, altered and degraded by man. Of the Mustelids, the Ferret Badger and the Hog Badger found in the Northeastern India take the pride of place not only because of their rarity but also because of their uniqueness. The Red Panda (*Ailurus fulgens*) is yet another flagship species of this region, restricted to the higher altitudes.

All the bear species that occur in India are recorded from the northeastern region. Besides, Northeast India forms the western end of the range for Malayan Sun Bear (*Helarctos malayanus*). Bears of the lower elevations are under especially serious threats owing to habitat degradation as well as persecution by man, as the bile of the animal is considered highly medicinal. Wild Dog or Dhole, is yet another rarity in the wilderness of Northeast India. Wild Dog found in Sikkim (and in Kumaon, Nepal and Bhutan) is considered *Cuon alpinus primaevus*. The *Cuon alpinus adjustus* found in

eastern Arunachal Pradesh is considered to be the same subspecies found in northern Myanmar.

Bats and rodents

Inventories, especially for bats and rodents, are wanting from Northeast India. Though, with about 65 species, bats dominate the mammalian fauna of Northeast India, reliable information available on them is sparse. The Wroughton's Free-tailed Bat (*Otomops wroughtonii*), recorded from the *Barapede* cave in North Kanara district of Karnataka was believed to be a narrow endemic. However, now it has now been reported from Siju Cave in South Garo Hills of Meghalaya in Northeast India, and also from Cambodia. The Government of India has listed the Wroughton's Free-tailed Bat in Schedule I of Wildlife (Protection) Act, 1972.

The Namdapha Flying Squirrel (*Biswamayopterus biswas*) is a little known narrow endemic found in the State of Arunachal Pradesh. It was first described from Deban in 1981. The Namdapha National Park, one of the largest parks in the country holds a number of other squirrels - Hairyfooted Flying Squirrel (*Belomys pearsoni*) and Particoloured Flying Squirrel (*Hylopetes alboniger*), Orange-bellied Himalayan Squirrel (*Dremomys lokriah*), Malayan Giant Squirrel (*Ratufa bicolor*), Hoary- bellied Squirrel (*Callosciurus pygerythrus*) and Himalayan Striped Squirrel (*Callosciurus macclellandi*) could all be seen in this park. The Hispid Hare (*Caprolagus hispidus*) is yet another habitat specialist that is facing the threat of elimination from the region.

Ungulates

Of the 28000 wild elephants in India, about 33% are found in Northeast India. In fact, Assam alone accounts for more elephants than Myanmar, Thailand, Indonesia or any other country in Asia. However, elephant population is dwindling sharply in Northeast India. There has been a very serious decline in the elephant population in central Assam whereas those in the southern parts have virtually vanished. The population has seriously declined in Tripura and there are only a few elephants left in Manipur and Mizoram and probably none in Nagaland. Heavy loss of prime elephant habitat is an issue of great concern as loss of elephant habitats heralds doom for smaller creatures as well.

Great Indian Rhinoceros (*Rhinoceros unicornis*) is the largest of all the rhinos now inhabiting the world. In Northeast India this species is now restricted to Kaziranga, Pabitora and Orang in Assam. The population at Manas in Assam is believed to have been decimated in recent years. Historical records suggest that both the One-horned Javan Rhinoceros (*Rhinoceros sondaicus*) and the Two-horned Sumatran Rhinoceros (*Didermocerus sumatrensis*) were once found in parts of Northeast India. Both the species are now extinct from the region.

The Water Buffalo (*Bubalus bubalis*) found in Northeastern India has a rather alarming

genetic problem. A large number of domestic buffalo, most of them genetically a 'cocktail species' bred by man, are grazed in the habitats of the wild buffalo and the interbreeding revitalizes the domestic strain but has the opposite effect on the wild strains. The Banteng (*Bos javanicus*) occurred in the hills of Manipur as late as 1990s, but is now not reported from the State.

The Brow-antlered Deer (*Cervus eldi eldi*) is endemic to the State of Manipur. Sangai, as the deer is locally known, is one of the rarest and the most localized subspecies of deer in the world. Reported to be extinct in 1951, this deer was subsequently discovered in a small pocket on the floating mats of vegetation, called 'phumdi' in the Loktak Lake. Though just fourteen heads were counted in the first aerial census in 1974, their number has steadily increased since then. Loktak Lake is now a RAMSAR site and there are now about 150 individuals in this undoubtedly the most fragile habitat of the region. The Swamp Deer (*Cervus duvauceli*) found in Assam is yet another Cervid of great conservation significance. The Serow (*Capricornis sumatraensis*), Goral (*Naemorhedus goral*) and Red Goral (*Naemorhedus baileyi*) are three other species that are of great conservation significance in the region. The Pygmy Hog (*Sus salvanius*) is the smallest and the rarest wild suid in the world, and only a few isolated wild populations survive in Northeast India.

Other mammals

In the State of Sikkim, at the heights above 3600 m. where the tree line ends, the alpine Scrub and grasslands support some of the most unique fauna of the planet, the Yak (*Bos grunniens*), The Tibetan Wild Ass (*Equus hemionus kiang*), Markhor (*Capra falconeri*), Ibex (*Capra ibex*), Great Tibetan Sheep (*Ovis ammon hodgsoni*), Blue Sheep (*Pseudois nayaur*), are only to name a few.

It is recorded that the Chinese Pangolin (*Manis pentadactyla*) ranges westwards through Assam and the Eastern Himalaya to Nepal, Myanmar and South China. However, the Indian Pangolin (*Manis crassicaudata*) is also reported from the Indo-Myanmar border areas and this confirms that both species exist in Northeast India.Ganges River Dolphin (*Platanista gangetica*) is yet another mammal of great conservation importance that can still be found in the Brahmaputra River in Northeast India.

Birds

Northeast India supports some of the rarest, least known and most sought –after birds of the Oriental Region. This region perhaps supports the highest diversity of bird species in the Orient. More than 400 species of birds are recorded from Kaziranga National Park alone in Assam and although not thoroughly explored, the State of Arunachal Pradesh has a record of 665 species of birds. Though birds are one of the most studied organisms, there is acute paucity of information concerning the avian fauna of the region and at the same time, new species are continuously being added to the region's list. The following account should provide a general picture concerning

the birds of Northeast India.

Poor dispersers such as babblers and laughing thrushes are important forest understorey passerines in the rainforests and they have diversified locally and contribute significantly to the diversity of the avifauna of Northeast India (they constitute about 10% of the Eastern Himalayan avifauna). The Brown-capped Laughing Thrush (*Garrulax austeni*) is only known from the hills south of the Brahmaputra in the North Cachar Hills (Assam), Nagaland, Manipur and Mizoram. The bird's habitat consists of oak and rhododendron forest, secondary growth and bamboo from 1200 m. to 2700 m.The Elliot's Laughing Thrush (*Garrulax elliotii*) and Brown-cheeked Laughing Thrush (*G. henrici*) are two species that have been recently added to the region's list, from Arunachal Pradesh. Both these species had previously been recorded only in China.

The Assam Plains and the Eastern Himalaya have been identified as Endemic Bird Areas by Bird Life International. The Assam Plains holds Blackbreasted Parrotbill (*Paradoxornis flavirostris*) and the Marsh Babbler (*Pellorneum palustre*) and in this region one can always hope to rediscover the Manipur Bush Quail (*Perdicula manipurensis*). The Eastern Himalayan part of Northeast India supports 22 restricted-range bird species (those that have a total world range of less than 50,000 square kilometres); of these 19 are endemics (see Table). Perhaps, with the exception of Manipur Bush Quail (*Perdicula manipurensis*), which is considered to be extinct, one could perhaps hope to see all the other 21 bird species in Northeast India, which holds one of the largest concentrations of globally threatened birds in Asia. The relatively high species richness of birds at high altitude zones in the region, compared with other taxa, is also notable.

White-winged Wood Duck (*Cairina scutulata*) is perhaps the rarest duck in the world today and this bird occupies the pride of place among the avifauna of the region. However, extensive destruction of its natural habitat ranging from Assam and Arunachal Pradesh to Java has pushed this species into isolated groups of small populations. Greater Adjutant (*Leptoptilos dubius*) is a globally threatened bird with the majority of the world's population now found in Assam. Spot-billed Pelican (*Pelicanus philippensis*), Blacknecked Stork (*Ephippiorhyncus asiaticus*), Lesser Adjutant (*Leptotilos javanicus*), and Pale-capped Pigeon (*Columba punicea*), are only to name a few of the globally threatened birds found in the region. Swamp Francolin (*Francolinus gularis*), found in Northeast India, is endemic to the Indian subcontinent. The Bengal Florican (*Houbaropsis bengalensis*) is one of the rarest bustards in the world. Manas National Park has the largest population of this bird in the world. Hornbills, too, exhibit high species richness in northeast India, found in few places elsewhere in the world.

Lesser Fish Eagle (*Icthyophaga humilis*) is the rarest of the fish and sea eagles, and there are reports of its sightings in Namdapha in Arunachal Pradesh. Jerdon's (Blyth's) Baza (*Aviceda jerdoni*) is a very rare resident bird of India, and the chances of sighting

this globally endangered bird are bright in evergreen forests of Northeast India. Burmese Hobby (*Falco severus severus*) is an uncommon breeding resident of Northeast India, south of Brahmaputra River. Pied Falconet (*Microhierax melanoleucos*) is also one of the rarest Indian raptors found in Northeast India.

The Sclater's Monal (*Lophophorus sclateri*) and Blyth's Tragopan (*Tragopan blythii*) are among the rare and beautiful pheasants that live in a limited range of the eastern Himalaya. With the exception of a status survey conducted on the Blyth's Tragopan in Blue Mountain National Park in Mizoram, which is recorded to harbour 38 birds, no detailed study has been carried out to date on these two species in any part of their range. It is even now a custom in certain hill areas of the region to present a Tragopan or Mrs. Hume's Pheasant (*Syrmaticus humiae*) to a visiting dignitary (to be slaughtered and eaten). All the pheasant species that occur in this region are to be considered endangered. Ward's Trogon (*Harpactes wardi*) is yet another beautiful resident bird reported from Arunachal Pradesh and Sikkim. The bird is sighted in the State of Manipur also.

Buff-throated Partridge (*Tetraophasis szechenyii*) is a rare resident of rocky ravines and Rhododendron thickets in the subalpine zone of central Arunachal Pradesh. At

Common Name	Scientific Name
Chestnut-breasted Hill-Partridge	*Arborophila mandellii*
Blyth's Tragopan	*Tragopan blythii*
Sclater's Monal	*Lophophorus sclateri*
Ward's Trogon	*Harpactes wardi*
Khasi Hills Swift	*Apus acuticauda*
Rusty-bellied Shortwing	*Brachypteryx hyperythra*
Black-browed Leaf Warbler	*Phylloscopus canator*
Broad-billed Flycatcher Warbler	*Tickelli hodgsoni*
Striped Laughingthrush	*Garrulax virgatus*
Brown-capped Laughingthrush	*Garrulax austeni*
Tawny-breasted Wren-babbler	*Speleornis longicaudatus*
Rusty-throated Wren-babbler	*Speleornis badeigualris*
Wedge-billed Wren-babbler	*Sphenocichla humei*
Rufous-throated Wren-babbler	*Speleornis caudatus*
Snowy-throated Babbler	*Stachyris oglei*
Hoary-throated Barwing	*Actinodura nipalensis*
Streak-throated Barwing	*Actinodura waldeni*
Brown-throated Fulvetta	*Alcippe ludlowi*
White-naped Yuhina	*Yuhina bakeri*
Grey Sibia	*Heterophasia gracilis*
Beautiful Sibia	*Heterophasia pulchella*

higher altitudes in Sikkim, birds include Snow Partridge (*Lerwa lerwa*), Blood Pheasant (*Ithaginis cruentus*), Himalayan Monal (*Lophophorus impejanus*) and Ibisbill (*Ibidorhyncha struthersii*).

The highly endangered Rufous-vented Prinia of the eastern population, regarded as a separate species 'Swamp Prinia' (*Prinia cinerascens*), is reported from the Pobitora

Wildlife Sanctuary in Assam. Beautiful Nuthatch (*Sitta formosa*) is a resident of primary forests of Northeast India. The Khasi Hills Swift (*Apus acuticauda*) is one of the world's rarest and least known *Apus* species, and is known only at its breeding cliff near Cherrapunjee in Meghalaya from late February to the end of April. The movements of this endemic bird outside the breeding period are largely undocumented.

Pink-headed Duck (*Rhodonessa caryophyllacea*), as its local name 'nganu kokngánbi' in Meitelon, suggests that it was once a common bird in Manipur and elsewhere in Northeast India. It is now extinct. India's only Buff-throated Warbler was collected from Meghalaya in 1953, and no further records exist in India. Rufous-bellied Eagle (*Hieraetus* kienerii) found in this region is also probably extinct. Burmese Peafowl (*Pavo muticus*), found in the Indo-Myanmar border areas, is also seldom sighted in the region.

Though there is less information about the migration routes of birds in Northeast India, the Brahmaputra River and her tributaries are thought to form a flyway for birds from Northeast Asia.

Lower Vertebrates

The reptilian fauna of northeast India has the greatest affinity to the Oriental, Indo – Malayan and Indo – Chinese regions. According to existing records, there are 137 species of reptiles in Northeast India, but in reality there could be many more species that are yet to be identified. With better sampling and studies on the herpetofauna, the number of species is expected to change considerably for each of the states and for the region as a whole.

Among the component of reptilian fauna, the Gharial (*Gavialis gangeticus*) found in Brahmaputra River is of great conservation significance. Northeast India has the highest diversity of turtles. Of the 26 species of non-marine chelonians reported from India, 19 are found in this region. However, the information on this group of reptiles is also quite inadequate as most of the available records concerning the known species available are from the Brahmaputra Plain and adjoining areas in lower Eastern Himalaya. The hill states, especially south of Brahmaputra basin, viz., Nagaland, Manipur, Tripura, Meghalaya and Mizoram, remain poorly studied.

As recently as 2000, a chelonian species -*Amyda cartilaginaea*, was reported from Mizoram as a first record for India, the previous range for this species being from southern Myanmar to central Vietnam, Laos, Cambodia, and Thailand. This species was not found to be particularly rare in the study area, but was not reported as no herpetofaunal survey had been conducted earlier in Mizoram. Asian Roofed Turtle (*Kachuga sylhetensis*) is endemic to the region. The Elongated Tortoise (*Indotestudo elongata*), Asian Brown Tortoise (*Manouria emys*), Narrowheaded Softshell Turtle (*Chitra indica*) and Indian Flapshell Turtle (*Lissemys punctata)* are very rare among the recorded species.

The lizard fauna of Northeast India is profoundly influenced by the Indo-Chinese connection. Published records indicate 20 lizard species from the State of Assam, and 18 species from the tiny state of Manipur. Of the three species of Monitor Lizards found in the region, *Varanus flavescens* is listed in Schedule I under Wildlife (Protection) Act, 1972. and listed in Appendix I of CITES. The Tokay Gecko (*Gekko gekko*) is the largest gecko alive today and is found in northeast India. The Burmese Glass Snake (*Ophisaurus gracilis*) is yet another interesting reptile of Northeast India.

Fifty eight species of snakes have been recorded in Assam and 34 from Manipur. *Python reticulatus*, the largest snake in India, is found in northeast India and *Python molurus bivittatus* is known from a single specimen from the Arunachal Pradesh, which was a first record for India. One can expect to sight both the snakes in 'Mouling National Park' in the Upper Siang District of Arunachal Pradesh. King Cobra (*Ophiophagus hannah*) is the most awe-inspiring reptile of the region. *Typhlops jerdoni, T. tenuicollis, Stoliczkaia khasiensis, Elaphe mandarina, Oligodon melazonotus, Xenochrophis punctulatus, Bungarus bungaroides, Trimeresurus jerdoni* are just a few examples of very elusive and rare snakes of Northeast India.

Existing records indicate the presence of 64 species of amphibians in the Northeast India but this figure again could be a gross underestimate as they are a poorly studied group in Northeast India. A survey of amphibians conducted in the State of Nagaland from 1998 to 2002 has resulted in 19 species as new records for the State and 5 species (*Megophrys wuliangshanensis, M. glandulosa, Amolops viridimaculatus, Rana humeralis* and *Rhacophorus gongshanensis*) as new records for India.

Only four species of caecilians, *Ichthyophis garoensis, Ichthyophis hussaini, Ichthyophis sikkimensis* and *Gegeneophis fulleri are* known from Northeast India. The Himalayan Newt (*Tylototriton verrucosus*) deserves a special mention, as it is the only species of Salamander known from India, occurring in Manipur, Khasi Hills and Sikkim in Northeast India. Hitherto, they were little affected by man, but use of the pesticides in paddy cultivation is posing a threat to the species.

Fishes are the most ancient and numerous of vertebrates. Over 24,000 species of fishes are known in the world, and – a majority of these are from warm tropical waters. Northeast India is exceptionally rich in freshwater fishes, and it is heartening to note that the region has been extensively surveyed, and accounts for 236 species. From the State of Manipur alone, 167 species of freshwater species belonging to 11 orders, 31 families and 84 genera are recorded. The fish fauna of Loktak Lake in Manipur comprises 64 species. Two of these species, *Monopterus albus* and *Osteobrama belangeri* are restricted in their distribution to the Yunan State of China, Myanmar, and in India only to the State of Manipur. The Loktak Lake also serves as the breeding ground for several species of migratory fishes eg. *Labeo dero, L. bata* and *Cirrhinus reba.*

Sone Lake (12.5 km long and 3.0 km. wide), is one of the biggest tectonic lakes in

Assam. It sustains 75 species of fishes under 24 families and 49 genera and of which, 20 species are widely distributed while 8 species are native to Northeast India. Despite a very high diversity of fresh-water fishes, Northeast India does not have many endemic species (the fish fauna of India contains 2 endemic families, both of which are absent from the region).

Invertebrates

The Biodiversity Strategy and Action Plan for Northeast Ecoregion suggests that 3,624 species of insects and 50 molluscs are recorded from the region. Butterflies and moths are by far the best-studied invertebrate organisms in Northeast India, and the region contributes the maximum number of species for the group in the country. A decade ago, 689 species of butterflies were recorded from the State of Sikkim. An ecological study on Mammals, Birds, Herpetofauna and Butterflies carried out in Teesta Basin, Sikkim, revealed nearly 350 species of butterflies in altitudes less than 900 m. (In the study area the family Nymphalidae is recorded to be the most species rich forming 50% of the observed species, followed by Lycaenidae and Pieridae (17.2% each). Papilionidae and Hesperiidae have relatively low species richness, forming only 8.6% and 7.0% of the species, respectively). As species richness in the study area was found to be far greater than that reported earlier, especially at higher altitudes, this particular study highlights the importance of altitudinal gradients in the distribution of butterflies, and in their conservation.

One of the largest known tropical Lepidoptera is the Atlas Moth (*Attacus atlas*), is not uncommon in many parts of Northeast India. *Princeps polyctor ganesa,* which occurs in Northeast India, is one of the most beautiful butterflies in the country, while, - *Erysmia pulchella* and *Nyctalemon patroclus* are very beautiful moths that occur in the region. It is pertinent to add that sericulture is an age-old occupation for some people in states like Assam and Manipur, especially in the 'Loi' community in Manipur who have rendered the skill of silkworm rearing and silk weaving to art form.

Honey bees, render very valuable ecological services like pollinating wild and cultivated plant species apart from producing honey, and their advanced eusocial behaviour has always been a source of fascination for man. Four indigenous species of honey bees are recognized from India: *Apis cerana, A. dorsata, A. florae and A. andreniformes.* Of these, *Apis andreniformis* is only known from a few specimens collected from Northeast India where the species is exceedingly uncommon. It is an unfortunate practice that people in certain parts of Northeast India not only consume the honey and larvae of this insect, but also fry and eat the honey bees themselves.

The colossal deforestation: loss of biodiversity

Deforestation

The primary vegetation in extensive areas of the Northeast India has been disturbed and modified and in some places destroyed by seismic activities, frequent landslides

and resultant soil erosion. While these natural causes have contributed only marginally to the change in vegetation type, it is the activity of Man that has led to the irreversible transformation in the landscapes and has resulted in colossal loss of biodiversity in the entire region. Human influences have pushed many species to the brink of extinction and have caused havoc to natural fragile ecosystems. Such devastations to natural ecosystems are witnessed almost everywhere in the region and is a cause of great concern.

Northeast India has 64% of the total geographical area under forest cover and it is often quoted that it continues to be a forest surplus region. However, the forest cover is rapidly disappearing from the entire region. There has been a decrease of about 1800 sq.km. in the forest cover between 1991 and 1999 (F.S.I., 2000). More worrisome still is the fact that the quality of the forest is also deteriorating, with the dense forests (canopy closure of 40% or more) becoming degraded into open forest or scrub. Though there is a succession of several edaphic formations, a vast area of land has already been transformed into barren and unproductive wastelands. This being the case, the statistics of 'more than 64 % of the total geographic area in this region under forest cover' could be misleading. For example, though the forest cover in Manipur extends to 78% of the total geographic area, only 22% of forest area is under dense forest cover and the rest has been converted to open forests.

Except in the Brahmaputra and Barak valleys of Assam where substantial areas are under agriculture, little of the land is available for settled cultivation. Hence, shifting agriculture or slash-and-burn agriculture is the major land use in Northeast India and extends over 1.73 million ha (F S I, 1999). Different agencies have come up with different figures concerning the total area under shifting cultivation (jhum) in the region. What is not disputable is that with an ever shortening jhum cycle, the other human influences have caused environmental degradation with disastrous consequences.

Though Northeast India is predominantly mountainous, the region is very rich in aquatic ecosystem diversity. A large number of *bheels*, ponds and marshlands in the lowlying and floodplain areas of Assam, Arunachal Pradesh and Tripura represent the diversity in lentic ecosystems. However, deforestation and the resultant loss of soil, especially in the hill areas, are leading to increased siltation of rivers and streams. The deep pools that are the favoured habitats of many species, are rapidly becoming shallow and choked with silt, leading to a decline in habitat. At the same time, swamps, marshes, and other wetlands are increasingly being reclaimed for urban and agricultural expansion.

The forests of Assam once acted as a sponge, absorbing the tremendous impact of the monsoons. The natural drainage of the vast northeastern Himalaya is channelled through Assam and with the loss of thick forest cover, Brahmaputra, one of the largest and fastest flowing rivers of the subcontinent is creating havoc in the State. Floods that have devastating effects are now common to Northeast India and protecting the

forests is one vital step in containing this terrible problem.

Balakrishnan (1981) gives a graphic description of decimation of the vegetation of the region. In 1851, J.D. Hooker, on his expedition to Jaintia Hills had collected seven headloads of live *Vanda coerulea* (Blue Vanda orchid) plants for cultivation in England. Balakrishnan states that after 100 years, during various field trips stretching from 1965 to 1970, he could hardly spot a dozen plants even in remote forest areas of Nertiang where Hooker had made his collections. This is an indication of the rate at which primary forests and the wealth it carries are being irrevocably destroyed.

As early as in 1986, while describing the state of affairs concerning the forests of Arunachal Pradesh, A.K. Agarwal remarked, "the economics of forestry hinges on not only how good the forests are, but how effectively and how intelligently they are utilized. On this point the Arunachal Pradesh's record is decidedly poor". It is unfortunate that over two decades, things have only worsened. In all, at present more than 700 species of plants from the Northeast India are facing the threat of survival in the wild.

Species loss

Raman, (2001), studied bird occurrence and abundance patterns in secondary successional and mature tropical rainforests in a shifting cultivation mosaic habitat in Dampa Tiger Reserve, Mizoram. He found that many forest bird species, especially those with ranges restricted to Northeast India declined in abundance or disappeared in successional fallows unless regeneration exceeded 10 years.

Studies conducted by Gupta and Kumar (1994) revealed that the Phayrer's Langur (*T. phayrei*) could survive in secondary forests, provided that regeneration is allowed to continue at least for 9-10 years. However, a progressively shortening cycle of shifting cultivation and degradation of forests poses a threat even for such adaptive animals. Similarly, studies conducted by Raman, (1997) reveal that arboreal mammal species such as Malayan Giant Squirrel (*Ratufa bicolor*), Pallas's Squirrel (*Callosciurus erythraeus*) and Hoolock are dependent on tall, undisturbed primary forests or at least, late successional vegetation (25 years old, or more). However, it is a stark reality that in most parts of Northeast India, fallow periods have declined to 5-10 years, and in some places may be as short as 3-5 years. With sharp decline in their populations, the role of birds, bats, ungulates and primates as seed dispersers is decreasing, leading to further impoverishment of the primary as well as the secondary forests.

Choudhury, (2003) while describing 'Meghalaya's Vanishing Wilderness' writes that there are good populations of Hoolock (*Bunopithecus hoolock*) *in* the forests of West Khasi Hills, but those are private and community lands and he is not too optimistic about their future there. It should be a matter of disquiet that only a meagre 4.4% of the geographical area is under State Forest department, the rest being land belonging

to other categories like Private Forest, Clan Forests, Community Forests, etc.

A vast majority of the indigenous inhabitants of this region are meat-eating in their food habits and almost all communities have expert hunters, trappers and fishermen. One can find bones, skulls and hides of large and small mammals in tribal huts. It should be noted that though the traditional practices of trapping, snaring etc of animals are carried out in very remote areas, in most parts of Northeast India shooting wild animals with guns is prevalent, giving very little chance for the denizens of the forests to recoup from such pressures. Besides, certain meat is valued as medicinal and such animals are persecuted as great efforts are made by a few individuals to seek such animals and bring back home their body parts.

In the past, the hunting/trapping was done with considerable prudence with many taboos and restrictions. For example, the Anaal Naga in Manipur did not consume turtle or tortoise meat. The Maram Naga did not eat pork and the Thangkhul Naga did not eat any member of the cat family. Unfortunately, such taboos no more hold any sway among the people now.

It is a great tragedy that in many parts of Northeast India some people poison the rivers, streams and other water bodies to get good catches of fish. Apart from using plant poisons, lime, DDT, copper sulphate (Cu SO4) and, other synthetic chemicals are being used for fishing. Some are even using dynamite and gelatine sticks for the same purpose. This has serious ill effects on the entire aquatic ecosystems. Fish stocks are being entirely wiped out; several species of amphibians, birds and other fish predators are also being affected in the process; and nothing is known as to what happens to human beings on consuming such poisoned fishes.

Northeastern India is often called India's forgotten corner and it was perceived that the remoteness of the place has helped preserve its biodiversity. However, the penetration of roads into interior areas has already exposed the local populace to market economy, unscrupulous urban traders and middlemen in most parts of the region. A series of proposed dams that are across Northeastern region may lead to submergence of vast tracts of rainforests. Comprehensive environmental impact assessments, which are mandatory as per the law of the land, reveal the possible danger that these projects pose to the biodiversity of the region.

Conclusions

The ethnobotanical knowledge among the people of Northeast India is praiseworthy. However, colossal deforestation and the loss of species in the region is a matter of serious concern. Some research findings speak contrarily to the widely accepted view that the slash-and- burn type of cultivation is destructive in nature. Whatever be the results of studies on jhum cultivation *per se,* it cannot be ignored that certain ecosystems such as the rain forests are highly susceptible to man-made disturbances and there is a crying need for areas to be free from jhum in order to conserve the region's unique biodiversity. It is recommended that every State shall have at least 5% of the geographical area under National Parks and Wildlife Sanctuaries, which

cover natural ecosystems and greater emphasis need be given towards anti-poaching measures in such protected areas. In order to achieve this, there ought to be an increase in forest personnel, who are appropriately trained and equipped, especially in the ranks of Forest Guard, Forester and Range Forest Officer. In areas outside the Protected Area Network, other forms of protection that involves participation of local communities should be followed. The impregnability of certain forests in Northeast India is a source of protection, as this factor itself offers some hope for the survival of many species.

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Chapter 2

BIODIVERSITY OF THE WESTERN GHATS
AN OVERVIEW

R J Ranjit Daniels

Introduction

The Western Ghats, also known as the Sahyadri Hills, are well known for their rich and unique assemblage of flora and fauna. Norman Myers included the Western Ghats amongst the 25 biodiversity hot-spots identified in the world. Geologically the Western Ghats may be divided into two segments. The hills north of the Krishna basin (largely Maharashtra and Gujarat) with fragile basaltic rocks are results of the same processes that gave rise to the Deccan trap. Isolated, conical, flat-topped hills occur here with steep sides, marked with striations. They seldom rise beyond 1500 m. South of the Krishna basin is the region of precambrian archean crystalline hard rocks (nearly 2000 million years old granites, schists, gneisses, quartzites, etc). Soils vary from humus rich peat in the montane areas to laterite in the lower elevation and high rainfall belts. Soils are generally acidic.

Arising abruptly from the narrow Konkan and Malabar coasts, these hills run 1600 km north-south between the river Tapti in Gujarat and Kanyakumari in Tamilnadu covering an area approximately equal to 160,000 sqkm. In the east, they slope gently towards the Deccan Plateau. The northernmost segment that extends into Gujarat merges in the east with the Surat Dangs. In the Nilgiris, Palanis and parts of Karnataka, the Western Ghats extend considerably eastwards, locally merging with the Eastern Ghats. Towards the south, the hill chain is divided into two by the Palghat Gap (a mere 13 km gap at its narrowest) rendering a physically homogeneous high altitude plateau into two rather distinct biogeographic units viz., the Nilgiris complex in the north and the Anaimalai-Palnis complex in the south. Here are found the highest peaks viz., Anaimudi (Anaimalai Hills) and Doddabetta (Nilgiri Hills), reaching well over 2695 and 2637m ASL respectively. Apart from these, a number of peaks reaching heights of over 2000 m are present in the southern half as that in Tamilnadu (Palnis) and Kerala (eg. Highy Wavy Mountains and Grass Hills).

Climatic conditions in the Western Ghats vary with the altitude and physical proximity to the Arabian Sea and the equator. Although the Western Ghats experience a tropical climate - being warm and humid during most of the year with mean the temperature ranging from 20°C in the south to 24°C in the north, the higher elevations experience subtropical climates and on occasions frost. Further, it has been observed that the coldest periods in the southern Western Ghats coincide with the wettest.

Whereas rainfall peaks of 9000 mm and above per year, are known locally, annual rainfall as low as 1000 mm are frequent in the east bringing the average to around 2500 mm. Interestingly, the total amount of rainfall received and the spread are not often correlated. Areas in the northern Western Ghats (in the State of Maharashtra) receiving the highest rainfall (locally over 9000 mm) experience dry weather over more than half the year. On the contrary, areas receiving much less rainfall in Kerala and closer to the equator experience rain almost all through the year. Much of the rainfall is received during the southwest monsoon season. Peak period of rainfall is July-August.

Origin and Prehistory

Peninsular India was part of the Gondwana land till about 150 million years ago, from which it split and started moving north. The northward drift which lasted about a 100 million years finally ended with the peninsula colliding with the Asian mainland 45 million years ago. Major geologic transformations took place as the peninsula moved northwards. Soon after detachment from the Gondwanaland, the Indian peninsula drifted over the Reunion Hotspots - localised volcanic centres in the earth's lithosphere, 200-300 km across, which have remained active for several million years. It was this event that happened some 120-130 million years ago that resulted in the uplift of the Western Ghats. Subsequently, there were a series of volcanic eruptions until around 65 million years ago giving rise to the extensive Deccan Traps. These volcanic episodes to a large extent moulded the northern third of the Western Ghats. Since the Western Ghats are the result of domal uplift, the underlying rocks are ancient - around 2000 million years old. The oldest of these rocks are found in the Nilgiris and the high ranges of the Western Ghats.

The uplifted crust of the earth bears a central axial region of weakness coinciding with the track of upliftment. Peninsular India broke along its line of weakness, and the western segment drifted westward into the sea (a process known as faulting), giving rise to the present day hill chain, the Western Ghats and the west coast. This happened during the Eocene (between 45 and 65 million years ago), even before India became part of the Asain mainland. At this time the peninsula also experienced a marked eastward tilt permanently changing the pattern of drainage. The western faulting led to 'river capture' and diversion of the easterly drainage to the west in many instances. The rivers Sharavathy and Kali in Karnataka are two classical examples of westerly diversion of drainage due to uplift and faulting. The Western Ghats thus represent a tectonically active region with high rates of uplift, high summit altitudes, steep slopes, deep gorges and large potential energy for erosion and correspondingly high sediment yields.

Modern biogeographers feel that the sp species of all vertebrates are endemic. Amongst vertebrates, endemism is the highest in amphibians (78% species), followed by reptiles (62%), fish (53%), mammals (12%) and birds (4%) (Table 1).

Table 1: Endemic species of the Western Ghats

Group	Total species	Endemic species	% Endemism
Angiosperms	4000	1500	38
Butterflies	330	37	11
Fishes	218	116	53
Amphibians	121	94	78
Reptiles	156	97	62
Birds	508	19	4
Mammals	120	14	12

Very little fossil evidence exists to reliably reconstruct the prehistoric biodiversity of the Western Ghats. What we do know is that the flora of the Western Ghats share elements with Africa, Madagascar and South America (eg., Family Bignonaceae; *Vinca rosea*, etc). Many species of invertebrates including a few species of butterflies are also shared with South America and Africa. Amongst freshwater fishes there are a few genera (*Notopterus, Barilius, Rasbora, Puntius, Labeo, Clarias, Aplocheilus, Mastacembelus, Garra, Aphanius*) that are common to India and Africa represented by one or more species in the Western Ghats. Species of amphibians (especially caecilians) and reptiles (snakes in the genus *Boiga* for instance) may well have been there ever since the Western Ghats came into existence. Most species of land birds and mammals that are seen in the Western Ghats today are those essentially derived from the eastern Himalayan-Malayan complex after peninsular India became part of Asia.

Table 2: Vegetation types of the Western Ghats

Vegetation type	Distribution	Dominant flora
Tropical evergreen forests	200-1500 m ASL; 2500-5000 mm rainfall	Emergents up to 60m; *Acrocarpus, Aglaia, Artocarpus, Calophyllum, Canarium, Cullenia, Dipterocarpus, Holigarna, Knema, Myristica*, etc
Moist deciduous forests	500-900 m ASL; 2500-3500 mm rainfall	*Bridelia, Pterocarpus, Sterculia, Pterospermum, Lagerstroemia, Tectona, Terminalia*, etc.
Dry deciduous forests	300-900 m ASL; 1000-2000 mm rainfall	*Albizia, Anogeissus, Bauhinia, Buchnania, Butea, Dillenia, Emblica*, etc.
Scrub jungles	200-500 m ASL; 300-600 mm rainfall	*Acacia, Carissa, Capparis, Flacourtia, Gardenia*, etc.
Sholas	Above 1500 m ASL; medium to high rainfall	Short trees, 15-20 m high; *Actinodaphne, Elaeocarpus, Eunymus, Michelia, Rhodomyrtus, Schefflera, Symplocos*, etc.
Savannas	1700-1900 m ASL; medium to high rainfall	Grass; *Chrysopogon, Arundinella, Eulalia, Heteropogon*, etc
High rainfall savannas	Montane; Extremely high rainfall	Herbaceous to shrubby cover; *Ligustrum, Rhododendron, Anaphalis, Strobilanthes*, etc.
Peat bogs	Above 2000 m ASL; High rainfall	Grasses, sedges and mosses; Carex, *Cyanotis, Cyperus, Eriocaulon*, etc.
Myristica swamps	Sea level to around 600 m ASL, medium to high rainfall	*Myristica, Knema, Hydnocarpus, Lophopetalum*, etc.

Flora

As early as 1904 Hooker had drawn attention to the distinct flora of the Western Ghats, which he called the 'Malabar' floristic region. The presence of Bambusae, Dipterocarpaceae, Guttiferae, Myristicaceae and Palmae (Arecaceae) has contributed to its distinctness. The various major vegetation types are tropical evergreen forests, moist deciduous forests, dry deciduous forests, scrub jungles, sholas, savannas including high rainfall savannas, peat bogs and *Myristica* swamps (Table 2).

Four thousand species of flowering plants are known from the Western Ghats. The gymnosperm flora is represented by *Cycas circinalis* (Cycadales), *Decussocarpus wallichianus* (Coniferales) and *Gnetum ula* and *G. contractum* (Gnetales). Amongst the lower plants around 320 species of pteridophytes, 200 species of bryophytes, 300 species of algae and 800 species of lichens are known. There are 600 species of fungi known from the Western Ghats.

Fifty-six genera of flowering plants are considered endemic to the Western Ghats. Recent studies have suggested that there could be 1500 species of flowering plants endemic to the Western Ghats. Although the exact number keeps varying with the author and time, what is of interest is that nearly 38% of all species of flowering plants in the Western Ghats are endemic. Sixty three per cent of India's evergreen woody plants are endemic to the Western Ghats.

Invertebrates

Scientific research on the invertebrates of the Western Ghats has largely been restricted to a few groups of organisms. As with any other tropical regions, the Western Ghats' invertebrate diversity is best known by the butterflies (Table 3). Amongst other insects, ants of the Western Ghats are better studied for their habits and ecology. While there are a number of studies undertaken on other invertebrates throughout the Western Ghats, few really address questions relating to ecology and biodiversity. Most of the studies on invertebrates are of a checklist nature or taxonomic.

Studies in Uttara Kannada district have suggested that ant species diversity in forests is linked to the woody plant species diversity. Elsewhere in the forests of Karnataka studies on ant communities have indicated that the common weaver ant *Oecophylla smaragdina* regulates the behaviour of other terrestrial ants that share its habitat. Whether such dominance by the weaver ant also has a bearing on the ant species diversity in the habitat is not yet clear. It has been observed that ants in the genus *Leptogenys* dominate ant communities in the Western Ghats.

Butterflies in the Western Ghats belong to five families, 166 genera and 330 species. Of these, 37 species are endemic. These 330 species of butterflies depend on over 1000 species plants for feeding and breeding. Diversity of butterflies in the Western Ghats is thus related to not only adult feeding habitats, but also larval food plants. Comparative studies on butterflies using selectively logged and unlogged forests in

Kalakkad-Mundanthurai Tiger Reserve has suggested that butterfly diversity tends to increase in selectively logged habitats. However, it has been pointed out that this increase is due to the invasion by ubiquitous species at the expense of habitat specialists such as *Idea malabarica*.

Table 3: Distribution of butterflies in the Western Ghats

Geography	**Families and species**					
	Papilionidae	Pieridae	Nymphalidae	Lycaenidae	Hesperiidae	Total
India	107	109	521	443	321	1501
Western Ghats	19	33	96	101	81	330
Kerala	19	31	95	93	76	314
Tamil Nadu	19	31	94	97	75	316
Karnataka	19	29	92	98	78	316
Goa	18	27	70	78	56	249
Maharashtra	13	24	59	71	40	208
Gujarat	11	23	41	51	32	158

Many parts of the Western Ghats are still poorly explored for their invertebrate biodiversity. At the workshop on 'Research priorities in tropical rainforests' held in Coimbatore (February 27-28, 2001) the status of malacological studies in the Western Ghats was reviewed. It was apparent that most of the earlier works in the Western Ghats have under-represented the number of species of land and aquatic snails.

A few studies in the Western Ghats have paid attention to aquatic invertebrates including molluscs. During the early 1980s, a study of aquatic insects in the Nilgiris indicated that human interference in the upper Nilgiris has apparently reduced the diversity of species in seemingly undisturbed areas as Silent Valley. A decline in the diversity of aquatic invertebrates has also been noticed elsewhere in the Western Ghats. Habitat loss and pollution in Pune City have been attributed as reasons for the decline of aquatic insects and molluscs.

Fishes

There are around 218 species of primary and secondary freshwater fishes in the Western Ghats. 53% of all fish species (116 species in 51 genera) in the Western Ghats are endemic (Table 4). Patterns of distribution and diversity of freshwater fishes in the Western Ghats are rather poorly understood. This is mainly due to the widespread construction of lakes, reservoirs and dams and the subsequent introduction of food and sport fish during the past 200 years. Despite the human interference of freshwater habitats in the Western Ghats, there are still some discernable patterns of fish distribution and diversity.

In general, the small and rapidly flowing hill streams support only a few species of specialised fish. Species poor fish communities are also seen in the higher elevation streams of the Western Ghats. Deep waters that are slow moving tend to support the

highest diversity of fishes in the Western Ghats. Very deep waters as that in lakes, reservoirs and dams tend to be ideal for large sized and introduced species of fishes. They are not suitable for many smaller species that inhabit shallow, clear and rocky pools and streams.

Table 4: Diversity of endemic fishes in the Western Ghats

Order	Family	No. of genera	No. of species
Cypriniformes	Cyprinidae	23	60
	Balitoridae	7	23
Siluriformes	Bagridae	3	6
	Siluridae	2	2
	Schilbeidae	2	2
	Sisoridae	2	7
	Clariidae	2	2
	Heteropneustidae	1	1
Beloniformes	Adrianichthyidae	1	1
Cyprinodontiformes	Aplocheilidae	1	1
Synbranchiformes	Synbranchidae	1	4
	Mastacembelidae	1	1
Perciformes	Chandidae	1	2
	Nandidae	1	1
	Cichlidae	1	1
	Belontidae	1	1
Tetraodontiformes	Tetraodontidae	1	1
7	17	51	116

From what little has been understood of the distribution and diversity of freshwater fishes in the Western Ghats, it is apparent that the streams and rivers in the south are more diverse, including a larger number of endemic species, than those in the north. A study of the freshwater fishes in the Kerala part of the Nilgiri Biosphere Reserve has suggested that the east and west flowing rivers in the region do not significantly differ in the number of species and those species exclusive to them – 69 species, 24 being exclusive in the east flowing rivers as against 68 species and 23 being exclusive in those flowing west.

Amphibians

One hundred and twenty one species of amphibians are known from the Western Ghats. The 121 species fall under 24 genera, six families and two orders. The family

ranidae (true frogs) has the largest number of species (49) amounting to 42% of the amphibian fauna of the Western Ghats. The next largest family is rhacophoridae (treefrogs) with 30 species (25% of the amphibian fauna) (Table 5). In general, there are more species of terrestrial and arboreal amphibians in the Western Ghats than aquatic ones.

There is a remarkable diversity of caecilians in the Western Ghats. 16 out of 20 species known in India occur in the Western Ghats; all 16 being endemic. Caecilians prefer moist soils rich in organic carbon (essentially derived from rotting wood and leaf litter). The highest diversity of species in any given landscape is noticed in the southern half of the Western Ghats.

Table 5: Taxonomic breakup of the amphibian fauna of Western Ghats

Order	Family	Genera	Species
Anura (Frogs/Toads)	Bufonidae	*Ansonia*	2
		Bufo	10
		Pedostibes	1
	Microhylidae	*Kaloula*	1
		Melanobatrachus	1
		Microhyla	3
		Ramanella	6
		Uperodon	2
	Ranidae	*Micrixalus*	7
		Nyctibatrachus	11
		Indiarana	8
		Limnonectes	9
		Hoplobatrachus	2
		Euphlyctis	2
		Rana	6
		Tomopterna	4
	Rhacophoridae	*Philautus*	22
		Polypedates	3
		Rhacophorus	5
Gymnophiona (Caecilians)	Ichthyophidae	*Ichthyophis*	7
		Uraeotyphlus	5
	Caecilidae	*Gegeneophis*	3
		Indotyphlus	1
2	**6**	**24**	**121**

Note: This table does not include the recently discovered amphibians and recent changes in nomenclature of Indian amphibians.

The north-south ranges of the 121 species vary from extremely widespread to highly restricted. Some are patchily distributed, while others show a more continuous distribution. Interestingly, species restricted to the south of 13° N latitude are more frequently patchily distributed. There is also a greater representation of species that prefer moist forests in those with patchy distribution. When the patterns are analysed on a latitudinal scale, it turns out that species including *Bufo melanostictus, Microhyla*

ornata, Ramanella montana, Euphlyctis cyanophlyctis, Limnonectes limnocharis, Hoplobatrachus tigerinus, Tomopterna breviceps and *Polypedates maculatus* are found over the entire range of the Western Ghats. These species (except *Ramanella Montana*) are also widespread in the country.

Most species are found in the altitudinal range of 0-1200 m ASL. Highest diversity of species is at 800-1000 m. Analaysis of the patterns of amphibian distribution in the Western Ghats has suggested that widespread rainfall, shorter dry season and a more uniform local climate have contributed to the high levels of diversity and endemism than elevation *per se*.

Reptiles

157 species of reptiles including a crocodile *Crocodylus palustris* is known from the Western Ghats. Majority of the reptile species are snakes. In all 97 species, representing 36 genera (2 genera of turtle/tortoise, 20 snake, 14 lizard) are endemic (Table 6). Endemism is highest amongst snakes, especially with the family Uropeltidae alone contributing 33 species. Amongst lizards, dwarf geckoes (*Cnemaspis* spp) and skinks (*Ristella, Lygosoma, Mabuya* and *Scircella*) have the maximum number of endemic species.

Table 6: Taxonomic breakup of reptilian diversity in Western Ghats

Group	No. of species	Endemic species
Turtles/tortoises	6	2
Crocodiles	1	0
Lizards	63	34
Snakes	87	61
Total	157	97

Ecological studies of reptilian communities in the Western Ghats are those limited to the Kalakad-Mundanthurai Tiger Reserve. Survey-type studies of reptiles in the Western Ghats have provided the most information on species diversity and habitat use. Higher diversity of species has been observed in the moist deciduous forests. As per one study in the Nilgiris, the number of reptilian species is negatively correlated with altitude, but positively correlated with number of herbs, number of fallen logs and slope. However, detailed studies in the Kalakad-Mundanthurai Tiger reserve have suggested that mid-elevations of 1000-1100m ASL in the Western Ghats have the highest diversity of reptiles. Further, the density of forest floor reptiles in the Western Ghats is generally low being 0.26 per 25 sqm. It is interesting to note that snakes dominate the forest floor reptilian communities at altitudes of 1200m ASL and above.

Birds

Of all organisms, birds are the best studied in the Western Ghats. Beginning in the 1860s, British naturalists and planters were busy surveying the Western Ghats, collecting and describing the avifauna. Subsequent surveys by the Bombay Natural

History Society (then led by Dr Salim Ali), the various state departments of forests, especially Kerala, many nature clubs and amateur birdwatchers have suggested that there are 508 species of birds, represented by nearly 600 forms of resident and migratory birds. Amongst the 508 species, 144 (28%) are aquatic birds including those which are found in the coastal habitats. A total of 324 species (64%) are resident. These are predominantly land birds. Nineteen species may be considered endemic to the Western Ghats (Table 7).

Table 7: Endemic birds of the Western Ghats

Nilgiri wood pigeon	*Columba elphinstoni**
Malabar parakeet	*Psittacula columboides**
Malabar hornbill	*Oxyceros griseus*
Whitecheeked barbet	*Megalaima viridis**
Whitebellied treepie	*Dendrocitta leucogastra*
Malabar lark	*Galerida malabarica*
Greyheaded bulbul	*Pycnonotus priocephalus*
Rufous babbler	*Turdoides subrufus**
Rufousbreasted laughing thrush	*Garrulax cachinnans*
Greybreasted laughing thrush	*Garrulax jerdoni*
Wynaad laughing thrush	*Garrulax delesserti*
Black-and-rufous flycatcher	*Ficedula nigrorufa*
Whitebellied blue flycatcher	*Cyornis pallipes*
Nilgiri flycatcher	*Eumyias albicaudata*
Broadtailed grass bird	*Schoenicola platyura*
Whitebellied shortwing	*Brachypteryx major*
Malabar whistling thrush	*Myiophonus horsfieldii**
Nilgiri pipit	*Anthus nilghiriensis*
Crimsonbacked sunbird	*Nectarinia minima*

Note: Small and isolated populations of the species marked with an asterisk exist here and there outside the geographical limits of the Western Ghats in peninsular India.

Broad patterns of distribution and diversity have been discerned in the birds of the Western Ghats. In general, most of the resident and typically forest birds are restricted in distribution to the Western Ghats southwards from Goa. Few endemic species extend north of Goa. In general, the endemic bird species of the Western Ghats are primarily birds of the rainforests and the higher elevation shola-grassland complexes. In Kerala, the presence of some of the endemic birds (Malabar grey hornbill, Rufous babbler and Crimsonbacked sunbird) is associated with greater abundance of mammals such as Nilgiri langur, Lion-tailed macaque and Sambar.

Locally, when equal areas are compared, there are more species of birds per unit area in the central parts of the Western Ghats, especially in the Uttara Kannada district. This is primarily due to mixing of migrants and generalist species of birds with the resident specialists and endemics. Wet evergreen forests and montane sholas,

despite providing habitat to a number of specialists and endemic birds with greater conservation value, are comparatively less diverse in bird species than secondary/ disturbed evergreen and moist deciduous forests.

Human interference of forests has led to the disappearance of birds locally in the Western Ghats. However, when large landscapes are considered, species richness of the avifauna has remained stable during the past 100 years. Whereas the floristic composition of woody plants determine the nature of bird species that might inhabit a forest in the Western Ghats, bird species diversity may be inversely related to woody plant species diversity, locally. Monocultures in the Western Ghats may support an assemblage of birds as diverse as (or even more diverse than) evergreen forests. However, birds that inhabit the monocultures are often generalist habitat users drawn from a wide range of neighbouring habitats. Teak plantations may provide habitat to a number of species of birds in the Western Ghats. However, hole-nesting birds were found to avoid nesting on teak trees in monocultures.

Mammals

One hundred and twenty species of mammals are known from the Western Ghats. Fourteen species are endemic (Table 8). The mammalian fauna of the Western Ghats is dominated by insectivores (11 species), bats (41 species) and rodents (27 species including the porcupine). Few studies have however paid attention to the community structure and organisation of these small mammals in the Western Ghats although there have been attempts to review our understanding of the status and ecology of smaller cats and lesser carnivores.

Table 8: Endemic mammals of the Western Ghats

Madras hedgehog	*Hemiechinus nudiventris*
Day's shrew	*Suncus dayi*
Salim Ali's fruit bat	*Latidens salimalii*
Wroughton's free tailed bat	*Otomops wroughtoni*
Lion-tailed macaque	*Macaca silenus*
Nilgiri langur	*Trachypithecus johnii*
Nilgiri Marten	*Martes gwatkinsi*
Malabar civet	*Viverra civettina*
Brown palm civet	*Paradoxurus jerdoni*
Nilgiri tahr	*Hemitragus hylocrius*
Jungle striped squirrel	*Funambulus tristriatus*
Bonhote's mouse	*Mus famulus*
Ranjini's rat	*Rattus ranjiniae*
Malabar spiny dormouse	*Platacanthomys lasiurus*

Evergreen forests are particularly suited to frugivorous arboreal primates and squirrels while the deciduous forests offer the best habitat for the larger grazing herbivores like the gaur and deer. Drought resistant ungulates, particularly antelopes are specially adapted to the open dry scrub. Elsewhere in the Western Ghats of Karnataka, the distribution and biomass of large herbivores have been studied. From this it emerged

that the large herbivores biomass was highest in moist deciduous forests and adjacent teak plantations whereas it was the lowest in the dry deciduous forests.

Studies on other communities of mammals have been sporadic and more illustrative in nature. As mentioned before these studies have frequently addressed the smaller cats and lesser carnivores. Estimates of home ranges of civets and mongooses in the Western Ghats have suggested that the Indian Grey Mongoose (*Herpestes edwardsii*) and the Small Indian Civet (*Viverricula indica*) have monthly home ranges of 20.69-102 ha and 3.4-4.9 ha respectively. In another study of small carnivores in the Nilgiris it was found that civets were the most abundant (especially in evergreen forests) followed by mongooses, cats and marten. Canopy opening and the consequent weed infestation in evergreen forests adversely affects the civets.

At the scale of individual species, it has been found that endemic species of arboreal mammals including the spiny dormouse (*Platacanthomys lasiurus*) and the Nilgiri langur (*Trachypithecus johnii*) do not prefer evergreen forests that are either selectively logged or fragmented. The spiny dormouse is affected by habitat fragmentation. The food plants of the Nilgiri langur have been selectively lost in disturbed habitats.

The endemic primate *Macaca silenus* (Lion-tailed macaque or LTM) is amongst the few carefully studied mammals in the Western Ghats. In 1985, the population of this primate in the state of Karnataka was estimated as 3000. More recent estimates have placed the numbers in Karnataka around 1000-2000. A smaller population is known from Tamilnadu. Including the nearly 2000 individuals in Kerala, the population of LTM has been most recently placed at 4000. LTM is an inhabitant of evergreen rainforests, below 700 m ASL, with a home range of 1.25 sq km. Shape of the patches of these forests has a significant effect on the population of LTM. An opening of 0.5 sq km of canopy may block the path of a moving troop of LTM.

The Nilgiri Tahr (*Hemitragus hylocrius*) exists in the higher elevations between Nilgiris and Ashambu Hills in the Western Ghats. Over this 400 km range, around 2000 animals are estimated to occur: 150 in the Nilgiris, 570-690 in Anaimalais, 890 in Eravikulam, 280-310 in Palani Hills and a handful over the rest of the range.

Asian Elephant *(Elephas maximus)* is another species of mammal that has attracted both scientific and popular interest. Recent estimates place the population of elephants in the states of Karnataka, Tamilnadu and Kerala at 12,500. A majority of this population is within protected areas in the Western Ghats. Unlike the LTM, the elephant is more of a habitat generalist utilising a wide range of natural and man-made habitats in and around the Western Ghats.

The Tiger (*Panthera tigris*) is comparatively better studied amongst other large mammals. In the Western Ghats, the Tiger is presently restricted to states of Karnataka, Kerala and Tamilnadu. The exact population of this large and elusive cat is much less predictable than that of the Elephant, Nilgiri Tahr or LTM. Study of the natural food habits of larger carnivores in Nagarhole has suggested that the Tiger

selectively preys on animals weighing more than 176 kg. Non-selective predation by the Tiger on other animals is more likely the result of prey scarcity.

Human ecology and its impact on the biodiversity of the Western Ghats

The Western Ghats first came under human influences during the palaeolithic or old stoneage some 12,000 years ago (see Table 9). Stone tools used by palaeolithic people have been excavated in the river valleys of Palakkad, Mallapuram and Dakshina Kannada districts in the Western Ghats. Elsewhere, palaeolithic artifacts have been found in and around Mysore, Chickmagalur and Shimoga districts of western Karnataka.

Table 9: Chronology of human ecological events in the Western Ghats

Years before Present	Era	Ecological events
> 12,000	Palaeolithic	Hunting and gathering
12,000-5000	Mesolithic	Hunting-gathering, use of fire, forest decline and increase in savanna
5000-3000	Neolithic	Agri-pastoralism in the Deccan, vegetaion change in theNilgiris, coastal deforestation, use of iron, Harappan and Deccan immigrants into the Western Ghats
3000-1000	Megalithic	Agri-pastoralism, Western Ghats neoliths, shifting cultivation, decline in primary forests, sacred groves, extraction of spices and timber
1000-200	Historical	European trade, extraction of timber for ship building, increase in spice trade, organised agriculture, shifting cultivtion continues
200-100		Increased timber harvest, state forestry begins, Shifting cultivation regulated, natural teak depleted, Plantations initiated,
100-		Timber harvest intensified, timber stocks depleted, Conservation by state, mines, dams, townships

Mesolithic sites (12,000-5000 ybp) have been discovered around the river Mandovi in Goa. Charcoal beds dating back to 5000 ybp in Tenmalai (southern Western Ghats) suggest that humans burnt forests around this time. During the new stoneage (5000-3000 ybp) there were domesticated cattle, sheep and goats in and around the Western Ghats. Whereas rainfed crops including millets and horse gram were cultivated, in Maharashtra the Jorwe people cultivated wet rice. Shifting cultivation was apparently the form of agriculture that predominated the Western Ghats till recently. Crops such as *Eleucine coracana, Cajanus cajan, Ricinus communis, Panicum sumatrense,* etc were mainly cultivated in this traditional system of agriculture.

Human influences have had varied impacts on the biodiversity of the Western Ghats. History of species extinctions in the Western Ghats was certainly coincident with the climatic and human histories. Extended arid periods and human interference starting

12,000 years before present, led to slow but extensive transformation of habitats in and around the Western Ghats. Unique landscape elements such as the *Myristica* swamps gave way to cultivation of rice. Along with the swamps, trees such as *Myristica fatua* var *magnifica, Gymnacranthera carnatica, Semecarpus auriculata* and the palm *Pinanga dicksonii*, disappeared locally.

The use of fire to clear forests for cultivation has had a major influence on the forests of the Western Ghats. The spread of bamboo and deciduous trees in the region would have been aided by this human practice. Widespread occurrence of fire tolerant trees such as *Acacia catechu, Careya arborea, Dalbergia latifolia, Dillenia pentagyna, Schleichera oleosa, Tectona grandis, Terminalia spp* and *Xylia xylocarpa* suggests this.

Hill agroecosystems in the Western Ghats are today dominated by estates - chiefly of tea, coffee, rubber and monocultures of various tree species, including the oil palm, that was introduced lately. Available estimates indicate that above an altitude of 1500 m in the Western Ghats, there are 750 sq km of tea plantations. A total of not less that 1500 sq km are under coffee and 825 sq km under cardamom. It has also been highlighted that the Nilgiri district with a total area of 2549 sq km has around 1000 sq km under various forms of cultivation.

Casuarina plantations first appeared in Uttara Kannada district between 1868 and 1869. Till then the forest plantations were of native species. Teak was first raised as monocultures in 1840. The first teak plantation in Kerala was established in Nilambur in 1844. Over the years, eucalypts, cinchona, wattle, rubber, clove, etc, have displaced extensive patches of natural forests throughout the Western Ghats.

The impact of monocultures on the biodiversity of the Western Ghats has been little understood. In the Uttara Kannada district, monocultures were found to support as diverse a community of birds as natural forests. The bird assemblage may however include a greater number of generalist species than the natural forests. As mentioned above, teak when raised as a monoculture fails to attract hole-nesting birds.

Apart from the introduction of commercially important plants, there have been invasions by a number of aggressive alien plant species. The British Colonists spread over most of the Western Ghats in the late seventeen hundreds and early eighteen hundreds. The Nilgiris were colonised only in 1813 almost 2000 years after the Todas did. Much of the exotic flora, especially those of temperate origin, came in after this. A large number of ornamental plants of temperate origin have since run wild in the higher elevations of the Western Ghats. For instance, in Palani Hills alone there are 600 such species especially, around Kodaikanal. Similarly, 400-500 introduced species of plants have been reported from the Nilgiris.

Important amongst these are *Lantana camara* (var *aculeata*), *Eupatorium odoratum, Mikania cordata, Parthenium hysterophorus*, etc. Wattle (*Acacia* sp) once introduced

for the extraction of tannin in the higher hills is today a major threat to the sholas and grasslands at these altitudes. The impact of these exotic plants has been reason for a lot of debate. Contrary to general predictions, the presence of *Lantana camara* has not been detrimental to woody plant species diversity in the BR Hills.

In selectively logged evergreen forests, the woody plant species diversity has declined. This has been accompanied by the selective loss of certain plant species of greater economic value and an overall reduction in forest biomass. Other organisms have responded to human disturbance rather differently. Selective logging (consequently lower tree and canopy density) has locally increased the diversity of butterflies, lizards and birds in the Western Ghats. To balance the impacts of human interests with the long-term conservation of biodiversity in the Western Ghats is the greatest future challenge.

Acknowledgement

This summary is extracted from the National Biodiversity Strategy and Action Plan – Western Ghats Ecoregion, submitted to the Ministry of Environment and Forests, Government of India, in 2001. About 150 published and unpublished sources were consulted in the process.

Plate 1

Rhacophorous pseudomalabaricus : S.U. Saravana Kumar

Nilgiri Langur *(Trachypithecus Johnii)*: A.K. Gupta

Chapter 3

AN OVERVIEW OF INSECT DIVERSITY OF WESTERN GHATS WITH SPECIAL REFERENCE TO KERALA STATE

George Mathew and C.F. Binoy

Introduction

India, with its diversified ecosystems ranging from the snow-clad boreal forests in the Himalayas and tropical evergreen forests along the Western and Eastern Ghats, to the dry deserts of Rajasthan is considered to be one of the mega diversity countries. Of the various ecosystems, the Eastern Himalayas and the Western Ghats are known to harbour rich biodiversity. The latter is acclaimed as one of the 25 biodiversity 'hot-spots' of the world and thus occupies a critical position in the global biodiversity scene (Myers *et al.*, 2000).

The Western Ghats mountain range comprises of a series of hills running almost parallel to the west coast of Indian subcontinent from Tapti river in southeastern Gujarat to Kanyakumari in south Tamil Nadu. The 'ghats' descend steeply to the coastal plains on the west but merge rather gently through a series of hills in the Deccan plateau in the east. The western slopes receive rainfall of about 2000 mm per year and support luxuriant evergreen forests while the eastern slopes, which come under the rain shadow area harbour moist and dry deciduous types of vegetation. The area covers 1,59,000 km^2 with elevation ranging from sea level to 2,695 m.

Kerala State, located between 8^{0}4′ and 12^{0}48′N and 74^{0}52′ and 77^{0}37′ E is known for its rich biological resources on account of availability of a variety of ecological niches and habitats ranging from high forests, valleys, plains and coastal areas. Geographically, the State can be broadly divided into three zones *viz.*, highland (area lying above 75 m ASL), midland (area lying between 75 to 8 m ASL) and lowland comprising of areas situated below 8 m ASL. The highlands are formed by the Sahya Mountains of the Western Ghats along the eastern boundary, which are almost continuous except for a few gaps of varying width at certain locations. The Palakkad gap, which is the largest, has a width of 24-30 km. On its north are the Nilgiri Mountains and in the south are the Anamalais which has the highest peak, Anamudi situated at a height of 2695 m.

Kerala is bordered along its western side by the Arabian Sea. As a result, the State has a long shore area. This region, which is narrow having a width of 7 to 8 km, constitutes the lowlands. It constitutes roughly about 10% of the total geographical area of the State. The population of lowlands is very high compared to the other areas. The area lying between the highland and the shoreline is the midland, which roughly constitutes about 42% of the total geographical area. The valleys of the hill ranges, which have an altitude ranging from 300-600m ASL, belong to this. In the north, the Chaliyar River and the Nilambur valley separate the Kunda-Niligiri Mountains from Wayanad plateau located north to the Palakkat gap. Areas north to Palakkat gap belongs to Malabar comprising of the Districts Malappuram, Kozhikkode and Kannur. These areas are characterised by laterite belts, which are 10 to 60 m in altitude. South of Palakkad gap are the areas extending from Kochy to Thiruvanathapuram.

The climate of Kerala is generally tropical with high rainfall and humidity, which in turn

supports a luxuriant flora and fauna. The important vegetation types of this region are the tropical rain forests, tropical moist deciduous forests, tropical dry deciduous forests, montane shola forests, riparian forests, forest plantations, grasslands as well as agro ecosystems comprising of paddy, banana, vegetables and plantation crops such as arecanut, coconut, rubber etc.

Because of heavy population pressure, many patches of natural vegetation in Kerala are under threat. Of the total area of 38863 km^2, 10336 km^2 are forests. Incidence of fire, invasion by weeds, indiscriminate lopping of trees for fodder and firewood, introduction of plantations of exotics, establishment of hydro-electric and irrigation projects, encroachment as well as cattle grazing are the major disturbances to the forest ecosystems in this region. The agro ecosystem is also subject to disturbances due to filling of paddy fields, adoption of modern agricultural practices leading to large-scale application of chemical fertilizers and pesticides and fouling of wetlands. As a result, the microhabitats of many groups of organisms are affected which has tremendous implications on their survival. At present, we do not have any information on the species found in various ecosystems and their habitat preferences. For the conservation and sustainable utilisation of biodiversity, data pertaining to local biota is very important. Because of the large variety of species and diversified roles, insects have great significance both ecologically and economically. Although several surveys have been made on insects found in various ecosystems in Kerala, data generated for several groups still remains to be compiled. An account of the current status of research pertaining to the insect fauna of Kerala is presented here.

Brief summary of work so far carried out on the insect fauna of Western Ghats of Kerala

A strict differentiation into forest insects is not possible since insects found in other environments are also found in forests. Documentation of the Indian insect fauna has been initiated with the establishment of the British rule. Amateurs who made faunal surveys at various locations did much of the earlier works and either studied the material or passed them to experts in Europe. The results of these surveys are contained in the 'Fauna of British India' series. Since most of the above surveys were made in areas, which were easily accessible, or in areas close to human settlements, many locations particularly in formidable areas have been either poorly covered or not covered at all. Also, the intensity of sampling was low as indicated by data generated by subsequent workers especially of the Zoological Survey of India, various Universities and Research Institutions. For instance, in the Fauna of British India series on Moths, Vol. IV, Hampson (1896) described 1136 species from this region, out of which only 8 species were recorded as from Kerala. In contrast, he recorded 128 species from Nilgiris in the adjoining State of Tamil Nadu and 378 species from the neighboring island Sri Lanka (Ceylon). The common features exhibited in the geological and climatological features of Nilgiris and Sri Lanka with different parts of Kerala predict

rich pyralid fauna in this region. However, the inadequate surveys carried out in this part of the country are primarily responsible for the scanty records of these moths from Kerala as indicated by the number of species recorded in the subsequent studies by Hampson himself (Hampson, 1908, 1912, 1917, 1919, 1920, 1930) and by other workers (Meyrick, (1936-1937); Bleszynski (1961, 1964, 1970 a, b; Amsel (1968); Bradley (1969); Munroe and Mutuura (1969,1971); Arora and Mandal (1974); Roesler (1969) as well as Pajni and Rose (1978). As a result of these studies, about 500 more species have been added to the list of pyralids described by Hampson in 1896. Same is the case with other groups of insects such as Hymenoptera, Coleoptera, Isoptera, Thysanoptera, Hemiptera, Odonata and Collembola.

Several estimates on the fauna have been made from time to time. As per an estimate by Menon (1965), there could be about 50,000 insect species in India. According to a recent estimate by Varshney (1997), 59,353 species of insects belonging to 619 families, constituting merely 6.83 % of the world insect fauna, have been so far reported from India. The number would have been high but for the poor coverage of various ecosystems particularly the forest, which are known to be storehouses of great diversity. The estimate of insect species from Kerala is roughly 6,000 species (Nair and Easa, 1997). Most of the information generated by various workers lies scattered in the literature. In the absence of consolidated information on the fauna, no reasonable evaluation of the faunal specialties of the different regions is possible. It was in this context that an attempt was made herein to consolidate available data on various insect groups. Information generated for various groups is briefly summarized below.

Protura

Prabhoo (1972 a,b; 1975) listed 10 species belonging to the families Eosentomidae, Protentomidae and Acerentomidae, which included five new species.

Collembola

Prabhoo (1971 a, b) conducted detailed investigations on the Collembola of Kerala, describing sixty new species belonging to the families Neanuridae, Hypogastruridae, Onychiuridae, Anuridae, Brachystomellidae, Isotomidae, Entomobryidae, Neelidae and Sminthuridae.

Odonata

Fraser, Rao and Lahiri, Prasad and Kulkarni, Radhakrishnan, Emilyamma and Lakshminarayana have made valuable contributions to this group. Fraser in his 3 volume treatises on the odonates of the Indian sub continent gave a more or less detailed account of the fauna of Kerala. He (Fraser, 1933) described twenty new species of the family Platystictidae. In the next year (Fraser, 1934), he described thirteen new species of the family Gomphidae. Later, in 1936, he described seventeen new species belonging to the families Corduligastridae, Libellulidae and Aeschnidae. Rao and Lahiri (1982) conducted a preliminary study of the odonates of Silent Valley

and New Amarambalam reporting twenty-three species. Prasad and Kulkarni (2001) described thirty new species belonging to eight families. In the same year, Radhakrishnan and Lakshminarayana surveyed the Nilgiri Biosphere Reserve reporting eighty-eight species from the area. Emilyamma and Radhakrishnaan (2002) worked on the odonates of Parambikulam Wildlife Sanctuary recording twenty-five species and subspecies belonging to eighteen genera and five families. They also prepared a systematic database of this group in Kerala listing one hundred and thirty seven species under seventy-nine genera and twelve families (Radhakrishnan and Emilyamma, 2003). Asaithambi and Manickavasagan (2002) described five new species belonging to Gomphidae and Libellulidae.

Plecoptera

Zwick (1981) described six new species belonging to the family Perlidae.

Orthoptera

Hebard (1929) and Henry (1940) studied Acrididae. Shishodra and Kulkarni (2001) described twenty-seven new species belonging to Acrididae. Chopard (1969) described twenty-three new species belonging to the families Gryllidae, Gryllotalpidae, Myrmecophilidae, Pteroplistidae and Scleropteridae. Shishodra and Vasanth (2001) described five new species of Tettigonidae and two new species of Gryllidae. Cherian (1985) recorded six species of Orthoptera from the Idukki Hydal area. During 1979-'80, four faunistic explorations were conducted in the Silent Valley National Park wherein thirty-three species of Orthoptera have been recorded of which one was new (ZSI, 1986).

Phasmida

Two species have been described *viz.*, the leaf insect *Phyllium crurifolium* Audinet-Serville (Phyllidae) and the stick insect *Phasmida* sp. (Phasmidae).

Dermaptera

Burr (1910) has described eight new species belonging to Pygidicranidae, Forficulidae and Labiduridae.

Dictyoptera

Fourteen species belonging to the families Cryptoceridae, Blattidae, Mantidae and Empusidae have been described from Kerala which included the extremely rare woodroach *Dicellonotus* sp. which breed in rotting wood in wet evergreen forests. Cherian (1985) recorded two species of Dictyoptera from the Idukki Hydal area.

Isoptera

Fifty-six species of termites belonging to the families Hodotermitidae, Kalotermitidae, Rhinotermitidae and Termitidae haye been reported from Kerala. Bose (1984) described

32 new species belonging to the families Kalotermitidae and Rhinotermitidae. Chhotani (1970) and Verma (1983, 1984 a, b; 1986) described six new species of the families Kalotermitidae, Rhinotermitidae and Termitidae. Bose (1975), Thakur (1981) and Varma (1990) have recorded several species of termites affecting forest trees from Kerala.

Psocoptera

Over thirty species of psocids have been listed from Kerala by Menon (1939). They belonged to the families Lepidopsocidae, Psoquillidae, Amphientomidae, Caeciliidae, Pseudocaeciliidae Amphipsocidae, Stenopsocidae, Peropsocidae, Archipsocidae and Psocidae.

Siphunculata

Four species of importance in public health, belonging to the family Pediculidae have been reported.

Hemiptera

Distant (1904, 1906, 1908, 1910, 1916, 1918) made detailed studies on the Hemiptera describing seventy-four new species. Dworakowska (1980, 1981 a, b; 1992 a, b) described twenty-seven species of leaf hopers; Dash and Viraktamath (1998, 2001) fifteen species; Viraktamath (1998), Viraktamath and Wesley (1988) seventy-four species; Maicykutty and Usha (1995, 1996, 1997, 2002) nineteen species and Abdulla (1984) nine species.

The whiteflies were studied by Meghnathan and David (1994) describing sixty-four species and Sunderaraj and David (1993) eight species; Tirumalai (2001), thirty-nine species. Thirumalai and Radhakrishnan (1999) studied the aquatic Hemiptera of Kasargode listing fifty-eight species. Tirumalai *et al.* (2003) prepared a synoptic list of Gerromorpha from Kerala listing one hundred and twenty eight species under forty-four genera and five families. Coccidae have been studied by Rai (1984) and species of economic importance have been listed by Fletcher (1920) and Nair (1978). Mathur (1975) studied Psyllidae listing out species of economic importance. Hollis and Martin (1993) revised the genus *Padukia* and made some generic transfers. During 1979-'80, four faunistic explorations were conducted in the Silent Valley National Park wherein thirty-nine species of Hemiptera (six new) and two species of Homoptera (both new) have been recorded (ZSI, 1986). Cherian (1985) recorded six species of Hemiptera from the Idukki Hydal area.

Thysanoptera

Ananthakrishnan and Sen (1980) described one hundred and twenty one species of the family Thripidae. Later, Bhatti and Ananthakrishnan (1972 a, b; 1976) and Ananthakrishnan and Varadarasan (1978) described several new species of the family Merothripidae and of the gall forming thrips. Rai (1984) described three species of the family Phloeothripidae and Bhatti (2000) two species of the family Aeolothripidae.

Neuroptera

Only a few species are reported from Kerala and there has not been any exhaustive study of this group.

Coleoptera

With regard to Coleoptera, excellent faunal treatises have been prepared by Horn (1905) who described fifteen new species from Kerala; Gahan (1906), also on Cerambycidae; Fowler (1912) on Cicindelidae, describing fifteen species; Jacoby (1908) as well as Maulik (1919) on Chrysomelidae describing thirty one species and sixteen species respectively; Andrews (1929) on Carabidae describing six species; Arrow (1931) on Scarabaeidae describing forty-eight species; Rai (1984); Mukherjee (1986) on Gyrinidae describing thirteen species; Biswas (1986) on Staphylinidae describing eighteen species from Silent Valley; Biswas and Chatterjee (1986) on Scarabaeidae describing twenty nine species and twenty seven species respectively. During 1979-'80, four faunistic explorations were conducted in the Silent Valley National Park wherein one hundred and twenty eight species of Coleoptera have been recorded. This included ten new species (ZSI, 1986). Stebbing (1914) and Beeson (1941) made an excellent treatment of economically important Coleoptera of the Indian subcontinent, which contained reference to species found in Kerala. The former contained references to thirteen species recorded from Kerala and the latter, forty-three species. Mathew (1982) conducted a survey of timber beetles of Kerala in which he recorded about one hundred species of beetle borers belonging to the families Cerambycidae, Bostrychidae, Lyctidae, Curculionidae, Scolytidae, Brenthidae, Platypodidae and Anthribidae affecting commercially important timber species in the State. He (Mathew, 1985) also made a report of the coleopteran predators of various timber beetles from Kerala. Cherian (1985) recorded nine species of Coleoptera from the Idukki Hydal area.

Diptera

Brunetti, Cherian, Joseph and Parui, and Singh and Ipe have made major contribution to this group. Details of taxa described by various authors are as follows: Brunetti (1912, 1920, 1923) described fifty-three species belonging to Tipulidae, Psychodidae, Mycetophagidae, Simulidae, Asilidae and Syrphidae. Culicidae was studied by Barraud (1934) who described forty-one species, Hiriyan *et al.* (2003) twenty-one species and Christophers (1933) sixteen species. van Emden (1965) described twenty species of Muscidae; Singh and Ipe (1973) thirty six species belonging to Agromyzidae; Joseph and Parui (1981, 1986, 1990) sixty nine species of Asilidae and Nandi (2002) eleven species of Sarcophagidae. Cherian (2002), and Drew and Reghu (2002) recorded thirty-nine and twenty-one species of Tephritidae. The latter from the Nilgiri Biosphere Reserve area contained eight new species.

Cherian (1985) in a study on the insect diversity in the Idukki Hydel Project reservoir

Table 1. Details of taxa described by various workers

Family	Name of contributor	Details of taxa described/ recorded
Ichneumonidae	Sudheendrakumar (1986, 1993) Mohamed (1977-1980) Beevi *et al.* (2000)	7 species 3 species 7 species
Braconidae	Sumodan and Narendran (1990) Narendran *et al.* (1994, 2002) Narendran and Rema (1996) Beevi *et al.* (2000) Sudheendrakumar (1986,1993)	5 species 11 species 3 species 8 species 3 species
Chalcididae	Mani *et al.* (1974); Narendran (1976, 1985 b, 1986, 1987 a, b, 1994, 1996) Joseph *et al.* (1970 a, b; 1973 a, b, 1976) Mohamed (1977-1980) Beevi *et al.* (2000) Sudheendrakumar (1986, 1993)	23 species; 55 species 43 species 7 species (5 species)
Torymidae	Joseph (1954) Narendran (1994) Narendran and Sureshan (1988) Abdurahiman and Joseph (1967a, b; 1975 a, b; 1976)	3 species 58 species 8 species 11 species
Eurytomidae	Mani *et al.* (1974) Narendran (1994) Narendran and Padmasenan (1989, 1991)	3 species 40 species 5 species
Pteromalidae:	Sureshan and Narendran (1990, 1994 a, b; 1997) Beevi *et al.* (2000)	167 species 8 species
Encyrtidae	Mani *et al.* (1974) Beevi *et al.* (2000) Hayat *et al.* (2003)	4 species 3 species 1 species
Eupelmidae	Narendran (1996) Narendran and Anil (1995) Narendran and Sheela (1996) Beevi *et al.* (2000)	6 species 10 species 2 species 2 species
Eulophidae:	Surekha and Narendran (1992, 1993) Beevi *et al.* (2000)	5 species 8 species

Family	Name of contributor	Details of taxa described/ recorded
Scelionidae	Mani and Sharma (1982) Beevi *et al.* (2000) Narendran (1998) Narendran *et al.* (2001 a, b) Rajmohana and Narendran (2001a, b)	26 species 12 species 4 species 3 species 3 species
Trichogrammatidae	Beevi *et al.* (2000)	2 species
Mymaridae	Beevi *et al.* (2000)	6 species
Proctotrupidae	Rajmohana and Narendran (1996)	4 species
Diapriidae	Rajmohana and Narendran (1999, 2000 a, b; 2001a, b)	7 species
Ormyridae	Narendran (1999 a) Narendran et *al.* (1990)	7 species 1 species
Platygastridae	Mani and Sharma (1982) Beevi *et al.* (2000) Ushakumari (2002)	3 species 3 species 20 species
Tetracampidae	Narendran and Ramesh Babu (1996)	6 species
Chrysididae	Bingham (1903)	6 species
Scoliidae	Bingham (1903)	7 species
Mutillidae	Bingham (1903)	1 species
Formicidae	Suresh et *al.* (1999) Sheela and Narendran (1998)	12 species 4 species
Eumenidae	Bingham (1903) Suresh et *al.* (1999)	3 species 4 species
Pompilidae	Bingham (1903)	9 species
Vespidae	Suresh et *al.* (1999)	2 species
Sphecidae	Bingham (1903) Sudheendrakumar (1984)	6 species 44 species
Colletidae	Suresh et *al.* (1999)	1 species
Halictidae	Narendran et *al.* (2000)	1 species
Megachilidae	Suresh et *al.* (1999)	3 species
Anthophoridae	Suresh et *al.* (1999)	3 species
Apidae	Bingham (1903) Suresh et *al.* (1999)	11 species 7 species

complex made special attempts to study three dipteran families *viz.*, Tephritidae, Agromyzidae and Chloropidae. He reported fifteen species of Tephritidae representing 9.4%; fourteen species of Agromyzidae representing 10.8%; and ten species of Chloropidae representing 5% of the known species in India. Radhakrishnan (2002) prepared an inventory of Tephritidae of Nilgiri Biosphere Reserve recording thirty-five species under twenty-five genera and four subfamilies of which, nine species were new to science and four genera as new records for India. Radhakrishnan (2002) further studied this group at Eravikulam National Park listing nine species under nine genera and two subspecies.

Lepidoptera

Hampson (1894, 1895, 1896), Meyrick (1936- 1937), Talbot (1947) and Wynter-Blyth (1957) have made excellent contributions on the butterflies and moths of this region. Subsequently, several workers like Bleszynski (Crambidae), Francy (Noctuidae), Hampson (Moths), Larsen (Butterflies), Mathew (Moths and Butterflies), Meyrick (Microlepidoptera), Munroe (Pyralidae), Radhakrishnan (Moths and Butterflies), Rahmathulla (Geometridae), Roesler (Phycitidae), Menon (Moths) and Wynter-Blyth (Butterflies) have worked on the taxonomy and ecology of various groups of Lepidoptera. These authors have reported several new taxa from this area which included five species of Hepialidae, two species of Arbelidae (Hampson, 1892); one hundred and sixty six species of Noctuidae (Hampson, 1894); twenty species of Arctiidae and eight species of Pyralidae (Hampson, 1896); one hundred and sixty three species of Noctuidae (Francy, 2000); hundred and forty species of pyralids (Mathew and Menon, 1984) and seventeen species of bagworms (Mathew and Nair, 1986). With regard to butterflies, thirty-seven species have been reported by Wynter-Blyth (1957); fifty three species (twenty-two species of Papilionidae, twenty species of Pieridae; two hundred and ninety nine species (from the Nilgiri Biosphere Reserve) by Larsen (1987, 1988); forty four species by Radhakrishnan and Lakshminarayana (2001); one hundred and eighteen species (from Periyar Tiger Reserve) by Jaffer Palot *et al.*, (1997) and over ninety species by Mathew (1990) and Mathew *et al.* (1998)(from Silent Valley National Park). Cherian (1985) thirty-five species of Lepidoptera from Idukki Hydal project area. Sreekumar and Balakrishnan (1998) studied the butterflies of Adirappally area reporting forty-four species. Investigations by Mathew and Mohanadas (2001) indicated survival of very specialised insect community in the extremely harsh climatic conditions of the montane shola forests of Munnar and Wayanad. Of the butterflies recorded by them, 11 were endemic and 5 having protected status. In another study on the insect fauna of New Amarambalam, Mathew (2002) recorded 860 species of insects belonging to 13 orders. The fauna contained a high proportion of rare and endemic species particularly of Lepidoptera. Of the 133 species of butterflies recorded, 28 were having high conservation value being either rare or endemic.

Trichoptera

Higler (1992) studied Trichoptera describing thirty-seven new species belonging to the

families Xiphocentronidae, Hydropsychidae, Molannidae, Leptoceridae, Philopotamidae and Rhyacophilidae.

Hymenoptera

The Fauna of British India series on Hymenoptera Bingham (1903) has given a good coverage of various hymenopteran groups. Subsequent to the publication of the Fauna Volume, various workers such as Abdurahiman and Joseph (1967 a, b; 1975 a, b); Hayat *et al.* (2003); Joseph *et al.* (1973 a, b; 1976); Narendran (1986, 1992); Narendran and Joseph (1975); Narendran and Sureshan (1989); Narendran and Sheela (1995); Sudheendrakumar (1990, 1993, 1994), Sudheendrakumar and Narendran (1985) and Wiebes (1980) have made valuable contributions to our knowledge of this group of insects. Besides updating the taxonomy of various families, these workers have described a large number of new genera and species from Kerala mostly from the forests. An account of some new descriptions of taxa by various authors under major hymenopteran groups is summarised in Table 1.

Recently, Sudheendrakumar and Mathew (1999) conducted a faunal survey of the macro Hymenoptera of the Parambikulam Wildlife Sanctuary reporting one hundred and eight species of hymenopterans belonging to fifteen families under fifty six genera (Binoy *et al.*, 1999). The families Sphecidae, Formicidae, Pompilidae and Apidae contained maximum number of species. Of the various species recorded, seven genera and eleven species are new reports for Kerala. The evergreen forests had the highest diversity followed by moist deciduous forests and teak plantations.

Conclusions

Because of the characteristic ecoclimatic conditions, the Western Ghats fauna is very unique comprising of elements drawn from different biogeographic zones, which have evolved, into characteristic 'species groups' over years of isolation. This has been shown in studies carried out at Silent Valley. A major share of the moths collected from this area had close resemblance to the Malaysian fauna, although significant differences have been noted by CAB (London) between specimens collected from Silent Valley and Malaysia, suggesting endemism due to geographical isolation. In addition to the above, occurrence of species having Palaearctic and Afro-tropical affinities has also been noted (Mathew, 1990). The proportion of rare and endemic species was also very high. It may be mentioned here that in a study of the Lepidoptera of Silent Valley, about 30% of the material collected could not be identified as the systematics of many groups is still in a preliminary stage and it may turn out that many species collected could be new. Similarly, phenetic variations have also been noted in species collected from Silent Valley and elsewhere in Kerala: for example, the arctiids, *Cyme gratiosa, Asura obsoleta* and *Cyana bianca* collected from different geographical regions were distinct. It is obvious that we are only just beginning to understand the vast diversity of insects that we possess in our forests.

Genetic diversity within species

Because of the greater variety of habitats and host variability compared to the more uniform agricultural systems, we might expect incidence and perpetuation of greater genetic diversity within species in forest ecosystems. However, we know practically nothing about the genetic diversity existing within species of insects present in forest ecosystems. Existence of different host races of the bagworm *Pteroma plagiophleps* Hamp., a minor pest of tamarind which became a serious pest of forest plantations of *Paraserianthes falcataria* in Kerala in 1977 and of the avenue plantings of *Delonix regia* about two and a half years later has been suspected (Nair and Mathew, 1988). Occurrence of light and darker forms of the larvae of the teak defoliator *Hyblaea puera* Cramer in the same population is well known, but its significance is not understood. In the use of parasitic and predatory insects in biological control, even minute differences in strains are very important. Aspects of genetic diversity within species will come to light only when species-specific population studies are initiated.

Conservation implications

The economic and ecological significance of various insects is not yet worked out except in a few cases. Because of their number and diversified habits, insects play important roles in the sustenance of natural ecosystems. Information pertaining to biodiversity and biological attributes of insects is very important in conservation programmes.

Suggestions for future course of action

Need for more intensive study of fauna

Conservation of biodiversity will be meaningless without knowing its components. The insects so far reported from the Western Ghats represent only a fraction, since several forest habitats in this area still remain unexplored. Even with material collected in previous surveys, a major share still remains to be identified due to lack of taxonomic expertise in various groups. Of the twenty-nine insect orders, only a few orders like Lepidoptera, Hymenoptera and Coleoptera have been studied in any greater details. Even in these cases, many families have not been fully studied. Therefore, serious efforts are needed to study the species found in different habitats and their role in the ecosystem particularly with regard to lesser-studied groups such as the soil insects (Protura, Collembola), Diptera, Neuroptera, Plecoptera, Hemiptera etc. Due to deforestation, conversion of natural forests to plantations and with more subtle changes to the forest climate and flora as a result of human activities, the species and genetic diversity of insects is being continuously eroded. But we however, have no systematic record on these changes. As has already been stated, such information is needed for the conservation and sustainable utilization of biodiversity. Lack of taxonomic expertise, financial assistance, neglect from administrators and forest managers etc., are some of the reasons for not being able to undertake comprehensive research on forest insect biota. Preparation of a database on insects so far reported from various parts of

the Western Ghats and preparation of a master plan to study the various groups are few major aspects that need to be considered.

Information on the biota is a prerequisite for undertaking appropriate conservation strategies and this has been emphasized in the Convention on Biological Diversity (CBD) held in 1992. Documentation of biodiversity is the primary requisite for biodiversity conservation and therefore, in order to develop scientific conservation strategies, it is necessary to develop taxonomic skill. With the degeneration of taxonomic expertise in the current century, taxonomic investigations are at cross roads. It is the responsibility of administrators, environmentalists and all concerned with biodiversity conservation, to take necessary steps to document the existing biodiversity.

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Chapter 4

BIODIVERSITY OF INDIAN ASSASSIN BUGS (INSECTA: HEMIPTERA: REDUVIIDAE)

Dunston P. Ambrose

Biodiversity of Indian assassin bugs was analysed based on their taxonomical, ecological, structural, behavioural and biological characteristics. Three hundred and seventy species of assassin bugs under 106 genera and 15 subfamilies were recorded from Indian fauna limits. Members of Harpactorinae are the most abundant group with 136 species and 34 genera followed by Reduviinac and Peiratinae. Subfamilies such as Apiomerinae, Ectinoderinae and Physoderinae are represented by lone species, each. Majority of the assassin bugs preferred to live under boulders followed by shrubs, bark and litter. Many species share more than one microhabitat One hundred and eight per cent of assassin bugs were exclusively found in tropical rainforest, 26% in semiarid zone and 24% in scrub jungle. Many species occupy all the three major habitats as well as agro ecosystems. Haematophagous triatomines were found in human dwellings.

Structurally, majority of them have slightly curved rostrum (49%) followed by acutely curved (31%) moderately curved (15%) and straight curved *(5%)*. One hundred and sixty one species have tibial pads both in the fore and midtibiae whereas one species *(Sirthenea flavipes,* Peiratinae) has only in the fore tibiae. Alate reduviids are dominant (84%) followed by apterous (9%), micropterous (2%) and brachyptcrous (2%) forms. Polymorphism and sexual dimorphism in wing development and colour are observed. Reduviids glue and lay their eggs in batches or in isolation without gluing with intermediate types of egg lying in between.

Structural, behavioural and biological characteristics of reduviids belonging to different subfamilies were correlated to their habitats. The biodiversity of reduviids are discussed in terms of two major categories of tropical rainforest species and non-tropical rainforest species (scrub jungles and semiarid zones) and the structural, behavioural and biological diversities are correlated as adaptations to live in their respective habitats.

Introduction

Reduviidae is the largest family of predaceous land Hemiptera, containing about 6250 species and subspecies in 913 genera and 25 subfamilies (Maldonado, 1990). Reduviids are abundant, they occur worldwide and they are voracious predators. Hence, they are referred to as "assassin bugs". Being larger than many other predaceous land bugs and encamposing in their development a greater range of size, assassin bugs consume not only more prey but also a wider array of prey. Because they are polyphagous, assassin bugs may not be useful as predators on specific pests but they are valuable predators in situations where a variety of insect pests occur. Moreover, they kill more prey than they need to satiate themselves. Thus assassin bugs are important mortality factors and should be conserved and augmented for their utilization in biocontrol programmes (Ambrose, 1987; 1988; 1991; 1996; 1999; 2000; Schaefer, 1988; Schaefer and Ahmad, 1987).

Conservation of assassin bugs can be achieved only if their biosystematics and bioecology are studied thoroughly. One must know not only what the insect is, but

also what its relatives and what its phylogenetic relationships are; such knowledge broadens and deepens the biological information and thereby makes it more useful (Schaefer, 1988).

Despite the abundance of world's reduviid fauna and its rich taxonomic, geographic, ecological, trophic, morphological, biological and behaviour diversity and despite its prey record and biocontrol potential (Ambrose, 1996a,b; 1999, 2000), studies on reduviids are meagre. It is interesting to report here that what we know on assassin bugs is almost what we know on Oriental assassin bugs.

The author has been studying the bioecology, ecophysiology, ethology and biocontrol potential of Oriental assassin bugs, since 1976. His continued research yielded abundant information on the distribution and diversity of 370 species of assassin bugs recorded from Indian faunal limits (personal observation since 1976 (Ambrose, 1999, 2000; Murugan, 1988, Ravichandran, 1988; examination of reduviid collection of Prof. Carl W. Schafer, University of Connecticut, USA in 1997 and 1999, examination of museum specimens at Smithsonian Institute, Washington D.C., USA and Natural History Museum, London, UK in 1999). The information on distribution and diversity are discussed under the following headings: 1. taxonomical diversity, 2. ecological diversity, 3. structural and behavioral diversity and 4. biological diversity. This chapter attempts to give a holistic approach for better understanding of interaction on taxonomical, ecological, structural, behavioural and biological diversity of assassin bugs.

Taxonomical Diversity

The family Reduviidae contains more subfamilies than any other hemipteran family and their composition and relationship remains unsettled (Ambrose, 1999, 2000). Hence, there is an absolute need for a complete comprehensive reassessment of the family higher-level classification and phylogenetic relationship.

Distant (1902 and 1910) in his Fauna of British India, described 342 species of reduviids belonging to 106 genera and 13 subfamilies including Nabidae and treating Ectinoderinae under Ectrichodiinae, Physoderinae under Peiratinae and Centrocneminae, Reduviinae and Triatominae together as Acanthaspidinae. In this chapter, fifteen subfamilies with 106 genera and 370 species from Indian faunal limits are given (Maldonado. 1990).

Harpactorinae is the most dominant (37%) reduviid fauna with 136 species under 34 genera. Among harpactorines, *Coranus* and *Sphedanolestes* (17 species, each) dominated followed by *Rhynocoris* (3 species), *Sycanus* (12 species), *Endochus* (11 species) and *Rhaphidosoma* (six species), *Euagoras* and *Macracanthopsis* (five species, each), *Alcemna, Epidous* and *Irantha* (four species, each), *Biasticus* and *Brassivola, Isyndus,* and *Platerus* (three species, each), *Cosmolestes, Cydonocoris, Lanca, Ploididus, Rhirbus, Velinus, Vesbius* and *Villanovanus* (two species, each) and the remaining 10 genera are represented by one species, each.

The next abundant subfamily is Reduviinae with 61 species under 14 genera. Interestingly, 40 species (66%) belong to a single genus *Acanthaspis*. It is followed by *Edocla* with 5 species, *Empyrocoris, Pasira, Reduius* and *Velitra* are represented by two species, each. All the other eight genera are represented by one species, each.

Peiratinae follows Reduviinae in its abundance. It comprises of 44 species under nine genera. Interestingly, as observed for Reduviinae, the major constituents of Peiratinae too are from a single genus *Ectomocoris* (55%). It is followed by *Peirates* (20%). Except *Cleptocoris, Lestomerus phalantus* and *Sirthenea* (two species, each) all the other remaining three genera are represented by one species, each.

Stenopodainae very closely follows Peiratinae with 38 species under 11 genera. Here as observed for Reduviinae and Peiratinae, a single genus *Oncocephalus* holds the major constitutuents (55%). Two genera *Canthesancus* and *Pygolampis* have three species, each followed by *Aulacogenia, Caunus, Sastrapada,* two species, each. The remaining genera are represented by one species, each.

Ectrichodiinae very closely follows Stenopodainae with 34 species under 10 genera. The most abundant genera are *Haematorrhophus* and *Ectrychotes* (11 species, each). Except *Labidocoris* and *Scadra* (three species, each) the remaining six genera are represented by lone species, each.

Emesinae has 19 species under eleven genera. *Ploiaria* is the most abundant genus (four species) followed by Bagauda, *Emesopsis, Ghilianella and Myiophanes* (two species, each). All other six genera have one species, each.

Salyavatinae has 11 species under five genera. Unlike Reduviinae, Peiratinae and Stenopodainae, the distribution of species under five genera is not polarized. *Lisarda, Pefalocheirus* and *Paralisarda* possess three species each and *Nudiscutella* and *Valentina* only one species each.

Triatominae has six species. Here again five species are polarized in a single genus *Linshcosteus* and one species in *Triatoma.*

Remarkably, out of the seven saicines six are coming under a genus *Potytoxus*. Similarly out of the five species of Tribelocephalinae, three belong to one genus *Tribelocephala* and all two holoptilines are under the genus *Holoptilus*.

In *Centrocneminae* too, out of the four species, three belong to *Paracentrocnemis*. Subfamilies Apiomerinae, Ectinoderinae and Physoderinae are represented by lone species each. Distant (1902 & 1910) described four species and three genera under Apiomerinae and added that, few species of Neotropical apiomerines are found in Tropical and Ethiopian regions. But it is interesting as well as intriguing that except the lone specimen *(Ectinoderus* sp.) present in the collection of Prof. C. W. Schaefer (at present donated to me), my 25 years' field study could not yield a single aplomerine thereby suggesting its rarity or possible extinction in the tropical region.

Ecological Diversity

Ecological diversity of assassin bugs is discussed under two sub-headings: 1. microhabitat and 2. habitat.

Microhabitat

Assassin bugs have been recorded from four major microhabitats viz., under boulders, on shrubs, under the bark and in litter.

Analysis of data reveals that distribution and diversity of assassin bugs in relation to their microhabitats are well pronounced. For instance, out of the known microhabitats of 238 species, 82 species of assassin bugs (34%) live exclusively under boulders, 30 species (13%) on shrubs, 14 under the bark (6%) and 8 in litter (3%). The species, which are exclusively present in a particular microhabitat are considered to be endemic to the microhabitat. Endemism under boulders is more predominant followed by under the bark and in litter. Many species dwell more than in one microhabitat. For instance, 26 species (11%) dwell under boulders and in litter, 17 species in aerial and on shrubs (7%), six species, each under boulders and in crevices and under bark and litter (3%) and five species in shrubs and in filler (2%). Some species arc recorded from even up to four different microhabitats at different occasions. The microhabitats of 101 species are not known.

Microhabitats of apiomerines, ecunoderines and physoderines are not known. The known microhabitats of the centrocnemines are under boulders and in litter.

Ectrichodiines live only in concealed microhabitats. Out of the 34 ectrichodiine recorded, the majority of them (56%) live under boulders and thereafter under bark. Some species occupy more than one microhabitat. Interestingly, all the *Haematorrhophus, Scadra* and *Stegius* species recorded live only under boulders. This might be due to their larger size, which could not to be concealed under bark nor in dry litter and the availability of millipedes under boulders, their known prey.

Microhabitat of only 12 emesines is known. They are predominantly found underneath boulders and on vegetations. One emesine *S.susainathani* was collected from termitorium. *Empicoris, Ischnobaena, Ischnobaenella and Myophanes* species are found on vegetation and *Pfoiaria* species only under boulders except *P.nude* which is also found on bark.

Among the 136 species of harpactorines recorded, the majority of them are on shrubs. They occupy a variety of microhabitats such as underneath bark, in liner, under boulders and in termitorium. *Alcemna, Brassivola Cydnocoris, Endochus, Euagorcis, Iranttia. Lanca, Macraçanthopsis, Neonagausta, Neovillanovanus, Sphedanolestes* and *Vesbius* species are found either in flying or alighting on shrubs. *Coramis* species are found either in litter or underneath boulders, except two species which are also found on shrubs. *Sycanus* species are generally found on shrubs or under barks and rarely in litter. Members of *Rhaphidosoma, Platerus* and *Rhynocoris* are found underneath

boulders, in litters and on shrubs. *R.atkinsoni* is also recorded in termitorium.

The known microhabitats for holoptilines are under boulders or in litter.

Pciratmcs generally live under boulders (41%) and some of them are also recorded in the adjacent litter. *E.horridus* and *P.affinis* are also found under bark.

As observed for peirannes, reduviines generally live under boulders (43%) followed by in bark (13%). Many bark dwelling reduviines are recorded especially in the genus *Acanthaspis. Edocia, Mesacanthaspis, Neoacanthaspis Pasira, Pasiropsis* and *Paraknaeits* arc found only under boulders and some members also occupy nearby litter. Members of *Sminthocons* and *VeUtra* are dwellers of either under bark or in litter.

Members of Saicinae are recorded on shrubs (43%), in litter (14%) and on shrubs and in titter (14%).

Salyavatines are predominantly litter dwellers followed by living under boulders. *Lisarda* species are found underneath boulders and in litter whereas *Nudisciitella* species live only underneath boulders and *Paralisarda* species live only in litter.

Trialuminca prefer crevicca. *Linshcosteus* species are collected from crevices of buklera whereas *Triatoma* from crevices of human inhabitations.

Tribelocephalines live underneath boulders and very rarely in litter accumulated adjacent to the boulders (table 2, fig.2).

Habitat

The habitat diversity of assassin bugs is discussed with special reference to the three major ecosystems viz., tropical rainforest, semiarid zone and scrub jungle.

Habitats of 303 reduviids are known. Among them one hundred and eight reduviids (36%) exclusively dwell in tropical rainforest, 26 species in the semiarid zone (9%) and 24 species in scrub jungle (8%) ecosystems. Many species arc found in all the three major ecosystems (19 species, 6%) as well as in adjacent agroecosystem. Based on the habitat of known species of assassin bugs one can understand that they are more common in tropical rainforest and in semiarid zones and scrub jungles. Assassin bugs endemic to tropical rainforest rank greater in number than to semiarid zone and scrub jungle. It is emphasized, that many assassin bugs which are found in diverse habitats are also found in the adjacent agroecosystem. Many reduviids also share more than one major ecosystem. For instance, 23 species share semiarid zone and scrub Jungle, 19 species share scrub jungle and tropical rainforest and seven speciea share semiarid zone and tropical rainforest. Two triatommes are exclusively present in human dwellings. Twelve spedes were found attracted to light and two of them also found in agroecosystem. However, their actual habitat is not known.

Habitat of members of Apiomerinac, Ectmodermac and Physoderinae were not recorded. The known habitat of one centrocnemine is scrub jungle and tropical rainforest.

Seven ectrichodiines are exclusively present in tropical rainforest. Five species are found in both semiarid zone and scrub jungle. Similarly another six species are found in scrub jungle and tropical rainforest. Four species, *E.pilicomis, L..nigroyiolaceous, L.elegans* and *S.annulipes* are found in all the three ecosystems. Two species *E.abbreviatus* and *H.foveaus* are recorded from agroecosystem. Ectrichodiines are diurnal.

Except *Ploiara* species, all other cmesines arc recorded from tropical rainforest ecosystem or adjacent agroecosystem or as light attracted predators.

Sixty one harpactorines (45%) live only in the rainforest and eight species each in semiarid zone and scrub jungle ecosystem. *Alcemna, Biasticus, Brassivola, Cydnocoris, Endocjws, Epidaus, Euagoras, Irantha, Macracanthospis, Neonagusta, Neovl Uannvarms, Occamus, Panthcms, Rhirbus, SerencUba, Sphedcrnokstes, Sycemus,* and *yesbhis* species are found only in the tropical rainforest and are rarely seen in adjacent scrub jungles, generally at higher altitudes where tropical rainforest conditions prevail or adjacent semiarid zones or agroecosystem.

C.atncapilns, C.spmisciuis, C.vileuimis, R.fongifi-ons are found in scrub jungles, semiarid zones and adjacent agroecosystems. *P.brevispina* and *S.signatus* are seen in tropical rainforest, adjacent scrub jungle and agroecosystem. Many harpactorines found in the scrub jungles, semiarid zones and agroecosystems are also present in the aprons of localized tropical rainforest during summer when scrub jungle conditions prevail. *L.guerini is* present in scrub jungles, semiarid zone and tropical rainforest ecosystem. Three *Rhynocons* species *R.juscipes, R.kumarii, RJongifrons* and *C.soosai,* and *R.atkfnsoni* are recorded in all the three major ecosystems as well as in agroeosystems. A similar observation was noted for the holoptiline *H.melanospilus.*

Among Peiratinae, seven are exclusively present in tropical rainforest, four in semiarid zone and two in scrub jungle. *C.brevipennis, E.gangeticus* and *E. tuber'culatum* are seen in scrub jungles, semiarid zones and adjacent agroecosystems *E.nigrochripes, E.tibialis* and *P.affims* are found in all the three major ecosystems as well as in agroecosystem. The latter two are also found attracted to light. In Peiratinae, the habitat of many light-attracted species are not known.

Among Reduviinae as observed for *I. larpactorinae*, tropical rainforest harbours exclusively sixteen out of total sixty one species observed. Such exclusive presence is also found in scrub jungle and semiarid zone (eight and five species respectively). *A.apicata, A.flavipes, A.zebracid, Acanthaspis* sp., *P.nigerrima, R.delicatula* are recorded in the scrub jungles and semiarid zones. *A.subrufa* and *Acanthaspis sp.* share tropical rainforest and semiarid zones. Similarly, *C.dermata, E.maculatus* and *Paralenaeus* sp. share scrub jungle and tropical rainforest. Ten reduviines are found

in agroecosystem out of which seven belong to the genus *Acaniliaspis, A.pedestris, A.quinquespinosa, A.rama, A.sexguttata, A.siva, A.tergemma, A.trimaculata, E.slateri* and *V.sinensis* are found in all the three major ecosystem as well as in agroecosystem.

Two saicines are exclusively present in semiarid zone, one in semiarid zone and agroecosystem, one in tropical rainforest and agroecosystem and one in agroecosystem alone. Interestingly, none of them is found in scrub jungle. Out of the five species recorded, three are light attracted.

Among Safyavatinae, one species each in semiarid zone and scrubjungle and two species in tropical rainforest are exclusively present Three species, *L,annu!osa. N.frontispina* and *P.hrachialis* are found in all the three major ecosystems. *N.froniispina* is also found in agroecosystem and *P.brachialis* is found light-attracted.

Among 38 stenopodaines, six are exclusively present in tropical rainforest. Here comparatively more members (14 species) are found in agroecosystem. A single stenopodaine *O.nolatus* occupy all the three major habitats as well as in agroecosystem. Many species share scrub Jungle as well as semiarid zone as their dwellings.

Among triatomincs, *T.rvbrqfasciata and L.confnmus* and *L.castalis* arc recorded from human inhabitations and semiarid zone whereas a *Linshcosteiis* sp. from scrub jungle.

The habitat known for all the three tribelocephalines is tropical rainforest, but one species also lives in semiarid zone.

All the characteristic species of tropical rainforest are usually found in either arboreal or litter dwelling and are conspicuously diurnal. The semiarid zone and scrub jungle species are found usually in concealed habitats like underneath the boulders or the underside of loose bark of trees and they are crepscular.

Structural Diversity

Structural and behavioural adaptations of assassin bugs are intimately related with their ecological diversity. Hence, diversity of structure is analysed to understand their interrelationship with ecological diversity under three major distinguishable structures viz., rostrum, tibial pad and wing.

Rostrum

The rostrum of assassin bugs are categorized into four major types. They are straight, slightly curved, curved and acutely curved. Majority of the assassin bugs have slightly curved rostrum (49%) followed by acutely curved (31%), curved (15%), and straight rostrum (5%). Centrocnemines, ectrichodiines and physodermes live uniformly either acutely curved or curved rostrum except *N.therasii,* which has slightly curved rostrum. None of them has straight rostrum. Apiomerines, ectionoderines, emesines, holoprilines and triatomines uniformly have straight rostrum. Among harpactonnes, 11 species

have straight rostrum and 23 species have curved rostrum. None of them has acutely curved and others have slightly curved rostrum. Peiratines and reduviines have uniformly acutely curved 'bow' shaped rostrum. Saicines, salyavatines, stenopodaines and tibelocephalines have uniformly slightly curved rostrum (table 3, fig. 3).

Tibial pad

Assassin bugs are broadly grouped into two categories i.e., those with tibial pads or fossula spongiosae and those without tibial pads. Tibial pads are adaptive structural modifications of tibial ends involved in predation.

One hundred sixty one species possess tibial pads both in the fore-and midtibiae whereas *S.flcrvipes* (Peiratinae) has tibial pads only in forctibiae. Tibial pads are well developed both in the fore-and midtibiae of ectmoderines, ectrichodiines, physodermes and reduviines except in *N. therasii* of Ectrichodiinae and *P.nigerrima* of Reduviinae. The former has rudimentary tibial pads whereas the lattter has apical tibial pads. Members of Apiomerinae, Emesinae, Harpactorinae, Holoptflinae, Saicinae, Stenopodainae and Tribelocephalinae are generally devoid of tibial pads. But *C.picticollis* of Stenopodainae has well developed tibial pads. Differential level of rudimentary tibial pads and tibial combs are observed in many species of these six subfamilies. Except *S.flavipes* which has only the foretibial pad all other peiratincs have well developed tibial pads. '1 wo *Petalocheirus* species have rudimentary tibial pads and *L.annulosa* has apicalty projected tibial pads. Among Triatominae, two species have tibial pads both in the fore and midtibiae (table 3, fig. 4)

Assassin bugs exhibit diversity in wings. There are alate, brachypterous, micropterous and apterous reduviids. Moreover, in certain species alary polymorphism and sexual dimorphism are seen.

Alate reduviids *are* dominant (S4%) followed by apterous (9%), micropterous (2%) and brachypterous (2%) reduviids. Polymorphism and sexual dimorphism in wing development and colour with intersexual variations are seen in 12 species.

Apiomcrincs, ccntrocncmincs and cctinodcrines arc fully alate.

Among ectrichodiines *Ectrychotes* (except dimorphic *E. bharathi,) Guionius. Labidocoris, Stegius* and *Synectrochotes* are alate. *Neohaemcitorrhophus* is polymorphic. Aptery is almost totally pronounced in *Pfaem^toft-hophus* and *Hemihuematorrhophis* and partialiy (50%) in *Scadra.*

Among emesines, members *of Bagauda, Emesopsis, Empicoris, Gardena. Myiophanes* and *Stenolemus* are fully alate. *Ghilianella, Ischnobaena* and *Ischncbaenella* are fully apterous. *Ploiara* has both alate and apterous forms.

Except the apterous rhaphidosomatines all other harpactorines are alate.

Holptilines are only alate.

eggs laying pattern.

Egg laying habits of only 115 species are known. Fifty eight species glue their eggs with one another and to the substratum with cementing material whereas 57 species lay their eggs loosely (table 3; fig. 6).

Ectrichodiines lay elongately oval eggs loosely, except *N.therasii* and *Scadra* sp., which glue their eggs to the substratum. An emesine also lay elongately oval eggs loosely. Harpactorines lay elongate egg. Except *Rhaphidosoma* harpactorine, eggs are laid in cluster, glued to each other as well as to the substratum. The egg masses are generally exposed. Holoptilines also glue their elongately oval eggs. Peiratines lay elongately oval eggs loosely deep inside the soil. Reduviines lay globose eggs loosely in soil or crevices except the *Edocla* species, which lay their eggs in clusters. Reduiviines have the tendency to glue their eggs with their fresh excreta. Gluing of eggs to the fresh excreta is also observed in Peiratinae and Stenopodainae. Members of Salyavatinae, Stenopodainae and Triatominae lay globose eggs unexposed without any cementing material.

Based on the egg laying pattern, assassin bugs are categorized into five groups: 1) eggs laid in single cluster and cemented to each other partially and to the substratum (predominantly in Fetrichodiinae); 2) eggs laid in single cluster and the eggs are glued to each other longitidinally, basally and to the substratum (predominantly in Harpactorinae); 3) each egg individually cemented to the substratum in isolation (predominantly in Holoplilinac) 4) glued to fresh faecal matter (predominantly in Ectrichodiinae, Reduviinae, Peiratinae, and Stenopodainae and 5) eggs loosely strewn around erraricauy without any pattern (predominantly in Ectrichodiinae, Reduviinae, Peiratinae, Stenopodainae, and Salyavatinae). The endemic tropical rainforest species predominantly come under the two categories of egg laying whereas the scrub jungle and semiarid zone endemics exhibit categories 3 to 5 (table 3; fig. 6).

Biology

Apart from distinguishable adaptive structural and behavioural adaptations of endemic tropical rainforest forms in one hand and endemic scrub jungle and semiarid zone forms in the other hand, they also exhibit biological diversity.

Hatching percentage is comparatively greater among the harpactorines than among reduviines, peiratines, riatomines, stenopodaines and salyavatines, speparately. Generally, endemic tropical rainforest assassin bugs exhibit higher fecundity and hatchability than their counterparts in scrub jungle and semiarid zone. Eclosion and emergence periodicities in harpactorines are observed generally in forenoon and afternoon (diurnal) whereas these periodicities among the members of Reduviinae, Pairatinae, Triatominae, Stenopodainae and Salyavatinae are mostly found at dusk or at night (crepuscular). The incubation and stadial periods of tropical rainforest forms are shorter that those of scrub jungle and semiarid zone species. The endemics of

tropical rainforest are generally multivoltine with shorter stadia whereas those of scrub jungle and semiarid zone are univoltine or biovoltine with longer stadia.

Biocontrol agents

Fifty species are recorded as biocontrol agents. They are predominant among harpactorines (thirty four) followed by in reduviines (eight), peiratines (five), ectrichodiines (two) and stenopodaines (one). Biocontrol agents are not recorded from Apiomerinae, Centrocneminae, Ectinoderitiae, Emesinae, Holoptilinae, Physoderinae, Saicinae, Satyavatinae and Tribelocephalinae, (Fig. 17).

Domestic pests

Three triatomine domestic pests (haeniatophagous) are seen.

Discussion

Richest taxonomic diversity in terms of species diversity is apparently exhibited by harpactorines followed by reduviines. Though, 37 Peiratines are recorded, the species diversity is lesser (six genera) than that of Ectrichodiinae (31 species and 10 genera) and Stenopodainae (31 species and 11 genera). Emesinae though comprises lesser number of species (16) they are equivalent to that of Stenopodainae with eleven genera. Interestingly nine salyavaunes are grouped under four genera whereas six triatomines are present under only two genera. Members of Apiomerinae, Centrocneniinae, Holoptilmae, Physoderinae, Saicinae and Tribelocephalinae are represented by a genus, each. However, a species diversity index was calculated (Ambrose, 1999) by correlating the number of species and genera in a subfamily and considering the species number as unity and the genus number as proportionate value (of species unity). According to this calculation lower the index number greater the species diversity and accordingly subfamilies ofReduviidae are ranked as follows: Apiomerinae (1) < Ectmoderinae (1) < Physoderinae (1.0) < Emesinae (0.63) < Centrociteminae (0.5) < Ilolooprilinae (0.5) < Salyavatinae (0.44) < Stenopodainae (0.35) < Triatominae = Tribelocephalinae (0.33) < Ectrichodiinae (0.31) < Harpactorinae (0.24) < Reduviinae (0.22) < Saicinae (0.2) < Peiratmae(0.16).

Majority of the assassin bugs especially those living in semiarid zone and scrub jungle prefer to live in concealed microhabitats. Interestingly assassin bugs, which prefer exposed microhabitats are more common in tropical rainforests. Assassin bugs, which live in exposed microhabitats, are diurnal whereas those live in concealed microhabitats are crepuscular. Exposed microhabitats and diurnal behaviour are closely related to their wait and pin/jab/grab mode of feeding whereas concealed microhabitats and crepuscular behaviour are facilitating their chase and grab or pounce and grab mode of feeding. The former adaptation is suitable for tropical rainforest ecosystem where the prey fauna is not scarce whereas the latter is suited for prey-scarce semiarid zone and scrub jungle ecosystems.

Majority of the assassin bugs live in tropical rainforest. Out of the 303 assassin bugs reported in this chapter, 108 reduviids exclusively live in tropical rainforests. These species are considered endemic to tropical rainforest ecosystems. Such an endemism is comparatively very less for semiarid zone (26 species) and scrub jungle (24 species). It has been suggested that tropical rainforest is the ecosystem where reduviids have lived and they might have gradually inhabitated scrub jungle and semiarid zone as the transition of tropical rainforest to scrub jungle and to semiarid zone has taken place.

As the tropical rainforest transition to scrub jungle and semiarid zone has taken place, the once endemic tropical rainforest species have occupied scrub jungle and semiarid zone with structural behavioural and biological adaptations.

For instance, most of the tropical rainforest diurnal, exposed microhabitat living species are lightly coloured with a reddish tinge and without any warning colouration. Such a colouration helps the tropical rainforest endemic species to comouflage with die rich vegetation of their habitat. But most of the semiarid zones and scrub jungle assassin bug are crepuscular, concealed microhabitat living species exhibit warning colouration (Hack and yellow). The warning colouration of scrub jungle and semiarid zone assassin bugs are the characteristic feature of their drought pone, prey scarce ecosystem.

In addition to colouration, the cuticle of tropical rainforest endemic species is comparatively softer than that of scrub jungle and semiarid zones species, which have harder cuticle with rich sctose hairs, spines and tubercles. The harder cuticle with setose hairs, spines and tubercles is also an adaptation to withstand the drought prone climatic adversities and concealed microhabitats of semiarid zone and scrub jungle.

Non-tibial reduviid predators endemic to tropical rainforest are considered as timid predators since they do not employ their forelegs in prey capturing. During the course of evolution of their ancestoral saprophagy to carnivory and from timid predators to aggressive assassins, their maxillary stylets have also undergone structural as well as functional changes. Timid predators, which predate on smaller prey of tropical rainforest at random have relatively better formed maxillary barbs than aggressive predators of scrub jungles and semiarid zones. During the course of evolution loss of maxillary barbs, widening of salivary canal, increase of guidance of the route of the central stylet bundle, development of a maxillary lever that limits the protrusion of the central stylets, reduction of apical plate as intercalary plate of the rostrum and reduction in the mobility of last rostral segment might have taken place.

Endemic scrub jungle and semiarid zone species are also found withstanding prolonged starvation when compared to the tropical rainforest forms. It has been considered as an adaptation in the prey-scarce ecosystem. Moreover, the structural adaptations of the endemic species of scrub jungle and semi arid zone such as acutely curved rostrum as well as well developed tibial pads are correlated to their better predatory efficiency.

Generally the endemic tropical rainforest forms lay more number of elongate or elongately oval eggs in less number of batches or clusters and glue their egg masses either to the substratum or in the vegetation and egg masses are exposed.

The semiarid zone and scrub jungle forms lay lesser number of spherical or oval eggs in more number of batches, without any cementing material either in crevices or deep inside the soil. Their eggs are never found exposed in the field.

Tropical rainforest endemics have prolonged mating behaviour with a characteristic precopulatory riding, diurnal behaviour, exposed oviposition with higher fecundity in less number of batches of eggs, higher hatchability, shorter incubation and stadial periods, predominantly multivoltine etc. The tropical rainforest characteristics are more suited to the prey-rich, droughtless habitat with less threat from biotic (e.g. predators) and climatic adversities. In contrast, scrub jungle and semiarid zone endemics have short mating behaviour resembling aggressive predation, concealed oviposition with lesser fecundity in more number of batches of eggs, poor hatchability, larger incubation and stadial periods, predominantly univoltine or bivoltine etc. The scrub jungle and semiarid zone characteristics are more suited to prey-scarce, drought-prone habitats with more threat from biotic and abiotic adversities.

The structural, behavioural and biological adaptations of endemic assassin bugs of tropical rainforest, scrub jungle and semiarid zone can be better understood with knowledge on the transformation of tropical rainforest ecosystems into scrub jungle and to semiarid zone ecosystems.

The assassin bugs once predominantly present in the tropical rainforest ecosystem might have the following characteristics: 1) complex stylets and genitalia 2) timid predators, tibia without tibial pads or with tibial combs, spines, spurs etc. 3) fully alate 4) soft cuticle without warning colouration 5) generally polyphagous 6) predominantly arboreal and diurnal 7) gluing eggs basally and vertically in the form of a ootheca 8) exhibit congregational feeding 9) exhibit precopulatory riding during mating 10) high fecundity in less number of batches II)good hatchability 12) shorter incubation and stadial periods and 13) predominantly multivoltine. During the course of their migration from tropical rainforest to drought prone scrub jungle and semiarid zone, they might have attained the following characteristics: 1) loss of complex stylets and genitalia 2) aggressive predators with increased development of tibial pads 3) alary polymorphism, such as sexual dimorphism, aptery, brachyptery and alate condition 4) hard cuticle with warning colouration 5) increasingly monophagous 6) 22 predominantly crepuscular 7) gluing eggs only basally or buying individual eggs deep inside die soil or exhibiting tendency to glue the eggs to fresh excreta or ovipositing eggs solitary at random 8) adaptive nymphal camouflaging (Reduviinae and Satyavatinae) 9) lower fecundity in more number of batches 10) poor hatchability and 11) predominantly univoltine or bivoltine. (Ambrose, 1980; 1987a, 1987b, 1996, 1999, 2000; Livingstone and Ambrose, 1984; Vennison, 1988; Murugan, 1988; Ravichandran, 1988; Ambrose and Livingstone, 1989; Ambrose and Vennison, 1990a, 1990b; Vennison

andAmbrose, 1990; Sahayaraj, 1991; Kumaraswami, 1991; Rukmani, 1992; Kumar, 1993; and Das 1996; Ambrose and Ambrose, 1996a,b).

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Table 1
Biodiversity of Indian Assassin Bugs

ASSASSIN BUG	HABITAT	MICRO HABITAT	ROSTRUM	TIBIAL PAD		WING	EGGS
				Fore	Mid		
I. APIOMERINAE							
I. ECTMODERUS sp.	TR	-	S	-	-	AL	-
II. CENTROCNEMINAE							
2. *Neocenfrocnemis stal* Reuter	-	-	SC	+	+	AL	-
3. *Paracentrocnemis campelli* Miller	-		AC	+	+	AL	-
4. *P.dearmata (*Distant*)*	SJ,TR	BK,BS,LR	AC	+	+	AL	LS
5. *P. rugipennis* Miller	-	-	AC	+	+	AL	-
III. ECTINODERINAE							
6. *Amulius rubrifemur* Breddin	-	-	C	+	+	AL	-
IV. ECTRICHODIINAE							
7. *Ectrychotes abbereviatus* Reuter	AE	BS.LR	c	+	+	AL	-
8. *E. annamensis* Miller	-	-	C	+	+	AL	-
9. *E. atripennis (*Stal*)*	SJ,TR	BK,BS,LR	C	+	+	AL	LS
10. *E. bharathii* Murugan and Livingstone	TR*	BS, TR	C	+	+	SD	-
11. *E. comottoi* Lethierry	-	-	C	+	+	SD	-
12. *E. dispar* Reuter*	SJ,TR	BK,BS,LR	C	1	I	AL	LS
13. *E. pilicornis (*Fabricius*)*	SA,SJ,TR	BK,LR	AC	+	+	AL	-
14. *Ectrvchotes* sp.	TR*	BK,BS	AC	+	+	AL	LS
15. *Ectrychotes* sp.	TR*	BK	C	f-	+	AL	LS
16. *Ectrychotes* sp.	SA**	BS	C	+	+	AL	-
17. *Ectrychotes* sp.	SA, SJ	UK,BS	C	+	+	AL	-
18. *Eriximachus elobosus* Distant	SJ,TR	BS	C	+	+	AT	-
19. *Guionius nigripennis (*Tabricius*)*	SJ,TR	BS	C	+	+	AL	-
20. *Haematorrhopfus fovealis* Murugan and Livingstone	AE	BS	C	+	+	AT	-
21. *H. marginatus* (Reuter)	SA,SJ	BS	C	+	+	SD	-

22. *H. nigroviolaceous* (Reuter)	SA,SJ,TR	BS	C	+	+	AT	LS
23. *H. pedestris* (Distant)	SA,SJ	BS	C	+	+	AT	-
24. *H.ruguloscutellaris* Murugan & Livingstone	SA**	BS	C	+.	+	AT	-
25. *H.tuberculatus* (Stal)	SA,SJ	BS	C	+	+	AT	-
26. *Haematorrhophus* Sp.	SA**	BS	C	+	+	AT	-
27. *Haematorrhophus* Sp.	TR*	BS	C	+	+	AT	-
28. *Haematorrhophus* Sp.	SA,TR	BS	C	+	+	AT	-
29. *Haematorrhophus* Sp.	SA,SJ	BS	C	+	+	A).	-
30. *Haematorrhophus* Sp.	TR*	-	C	+	+	AL	-
31. *Hemihaematorrhophus planidorsatus* Murugan and Livingstone	TR*	BS	C	+	+	AT	-
32. *Labidocoris eleguns* Mayr	SA,SJ,TR	BK,BS	C	+	+	AL	LS
33. *L. tuberculatus* Vennison and Ambrose	SJ,TR	BK,BS	C	+	+	AL	LS
34. *Labidocoris* Sp.	TR*	BK	AC	+	+	AL	LS
35. *Neohaematorrhophus therasii** Ambrose and Livingstone	SA,SJ	BS	SC	•	•	PO	GL
30. *Scadra annulipes* Reuter	SA,SJ,TR	NS	C	>	< •	AL	-
37. *S. cincticornis* Kirby	SJ***	BS	C	+	+	AT	-
38. *Scadra* Sp.	SA**	BS	C	+	+	AL	GL
39. *Stegius prauss* Distant	SJ,TR	BS	C	+	+	AT	-.
40. *Synectrychotes calimerei* Livingstone and Murugan	SJ***	DK	C	'	'	AL	-
		V.EMESINAE					
41. *Bagauda avidus* Bergroth	TR*	AR,B	S	-	-	AL	-
42. *B. similis* Wygodzinsky	LA,TR	-	S	-	-	AL	-
43. *Emesopsis bimedia* Ravichandran and Livingstone	AE.LA	-	S	-	-	AL	-
44. *E. nubilus Uhler*	AE,LA	-	S	-	-	AL	-
45. *Empicoris rubromaculatus* (Blackburn)	TR*	BK,SB	S	-	-	AL	-
46. *Gardena muscicapa* (Bergroth)	AE, LA	•	S	-	-	Al.	-
47. *Ghilianella phasma* Distant	TR*	AR	S	-	-	AT	-
48. *Ghilianella* Sp.	-	-	S	-	-	AT	-

49. *Ischnobaena macerrima* Stal	TR*	BK,SB	S	-	-	AT	-
50. *Inschnobaenella invisibilis* (Dohm)	-	-	S	-	-	AL	-
51. *I.naraikkadu* Wygodzinsky	TR*	BK,SB	S	-	-	AT	-
52. *Myiophanes* Sp.	TR*	SB	S	-	-	AL	-
53. *Myiophanes* Sp.	LA	-	S	-	-	AL	-
54. *Phi aria anak* Distant	AE, SJ	BS	S	-	-	AT	-
55.*P.ussimilulu Van Duzee*	AE	BS	S	-	-	AL	-
56.*P.nude Ravichandran and Livingstone*	AL, SJ, TR	BK,BS	S	-	-	AT	-
57. *P.sondaniica Dispons*	SJ***	BS	S	-	-	AT	-
58. *Schidium phasma* (Distant)	TR*	AR	S	-	-	AT	-
59. *Stenolemus susainathani Wygodzinsky*	AE	BK,TM	S	-	-	AL	-
VI HARPACTORINAE							
60. *Alemena maculosa* Distant	TR*	AR	S	-	-	AL	-
61. *A. Sp.inifex* (Thunberg)	SJ, TR	SB	SC	-	-	AL	GL
62. *A. straminipes* Distant	-	-	SC	-	-	AL	-
63. *Alcmena* Sp.*	TR*	SB	S	-	-	AL	-
64. *Biasticus abdominalis* Reuter	TR*	-	SC	-	-	AL	-
65. *Biasticus fuliginous* Reuter	-	-	SC	-	-	AL	-
66. *Biasticus* Sp.	-	-	SC	-	-	AL	-
67. *Brassivola hystrix* Distant	TR*	-	SC	-	-	AL	-
68. *Brassivola* Sp.	TR*	AR,SB	S	-	-	AL	-
69. *Brassivola* Sp.	TR*	AR,SD	SC	-	-	AL	-
70. *Coranus ambrosii* Livingstone and Ravichandran	SJ***	BS	SC	-	-	AL	-
71. *C. atricapillus* Distant	AE,SA,SJ	BS,LR	SC	-	-	AL	GL
72. *C.carinata* Livingstone and Ravichandran	SJ***	BS	SC	-	-	AL	-
73. *C. emodicus* Kirischenko	-	-	SC	-	-	AL	-
74. *C. fuscipennis* Reuter	SJ***	LR	SC	-	-	AL	-
75. *C. nodulosus* Ambrose and Sahayaraj*	SA**	BS	SC	-	-	AL	GL
76. *C.ruthii* Livingstone and Ravichandran	SJ***	BS	SC	-	-	AL	-
77. *C. siva (*Kirkaldy*)**	SA,SJ	RS,TR	SC	-	-	AI,	GL
78. *C.soosaii* Ambrose and Vennison	AE, SA, SJ, TR	BS	SC	-	-	AL	G

79. *C.Sp.miscutis* Reuter	AE,SA,SJ	BS,LR	SC	-	-	AL	G
80. *C. vitellinus* (Distant)	AF.,SA,SJ	RS..I.R	SC	-	-	AI,	G
81. *C. wolff* Lethieny and Severin	SJ,TR	LR,SB	SC	-	-	AL	-
82. *Coranus* Sp. *	TR*	BS	SC	-	-	AL	GL
83. *Coranus* Sp. *	LA	-	SC	-	-	AL	GL
84. *Coranus* Sp.	TR*	LR	SC	-	-	AL	GL
85. *Coranus* Sp. *	SAJR	DS,LR	SC	-	-	AL	-
86. *Coranus* Sp. *	TR*	-	SC	-	-	AL	-
87. *Cosmolestes annulipes* Distant	-	-	SC	-		AL	
88. *C. picticeps* (Stal)	-	-	SC	-	-	AL	-
89. *Cydnocoris crocatus* Stal	TR*	AR,SB	SC	-	-	AL	GL
90. *C.gilvus (*Bunneister)*	SJ,TR	AR.SB	SC	-	-	AL	GL
91. *Edochus atricapius* Distant	TR*	-	SC	-	-	AL	-
92. *E.airispinus* Stal	TR*	SB	SC	-	-	AL	-
93. *E.cingalensis* Stal	TR*	AR,SB	SC	-	-	AL	GL
94. *E.erectus* Distant	-	-	SC	-	-	AL	-
95. *R.inomatus* Stal	SA,TR	AR,SB	SC	-	-	AL	GL
96. *E.migratorius* Distant	TR*	SB	SC	-	-	AL	-
97. *E.nigricornis* Stal	TR*	-	SC	-	-	AL	
98. *E.pasysspinus* Distant	-	-	SC	-	-	AL	-
99. *E.umbrinus* (Distant)*	TR*	AR,SB	SC	-	-	AL	GL
100. *Endochus* Sp.	TR*	AR.SB	SC	-	-	AL	-
101. *Endochus* Sp.	TR*	-	SC	-	-	AI.	GI.
102. *Epidaus atrispinns* Distant	-	-	SC	-	-	AL	-
103. *E.bicolor* Distant	TR*	-	SC	-	-	AL	-
104. *E.famulus* (Stal)	-	-	SC	-	-	AI.	-
105. *Epidaus* Sp.	TR*	-	SC	-	-	AL	-
106. *Euagoras erythrocephala* Livingstone and Ravichandran	TR*	SB	SC	-	-	AL	-
107. *E.plagiatiis (Bunneister)**	SA,TR	AR,SB	SC	-	-	AL	GL
108. *E.sordidatus* Stal	-	-	SC	•	-	AL	-.

109. Euagoras Sp.*	TR*	AR,SB	SC	-	-	AL	GL
110. Euagoras Sp.	LA	-	SC	-	-	AL	GL
111. Henricohania Sp.	-	-	SC	-	-	AL	-
112. HomaloSp.hoduss depressus (Stal)	-	-	SC	-	-	AL	-
113. Irantha armipes (Stal)*	SJ,TR	SB	SC	-	-	AL	GL
114. I.consobrina Distant	SJ,TR	SB	SC	-	-	AL	GL
115. I. consobrina Livingstone and Ravichandran	TR*	SB	SC	-	-	AL	-
116. Irantha Sp.	TR*	-	SC	-	-	AL	-
117. Isyndus heros heros (Fabridus)	-	-	SC	-	-	AL	-
118. Isyndus reticulates reticulates Stal	TR*	-	SC	-	-	AL	-
119. Isyndus Sp.	TR*	-	SC	-	-	AL	-
120. Lanca kandyensis Distant	TR*	-	SC	-	-	AL	-
121. Lanca Sp.*	TR*	SB	S	-	-	AL	GL
122.Lophoccphala gucrini (Laporte)	SA,SJ,TR	BS,CR,LR,SB	S	-	-	AL	GL
123. Macracanthospis hampsoni Duilani	TR*	SB	C	-	-	AL	-
124. M.nigripes Distant	TR*	SB	C	-	-	AL	GL
125. M.nodipes Renter	TR*	AR,F?B	C	-	-	AL	GL
126. Macracanthopsis Sp.	TR*	-	C	-	-	AL	-
127. Macracanthopsis Sp.	TR*	BK	C	-	-	AL	-
128. Narsetes longlnus Distant	-	-	C	-	-	AL	-
129. Neonagusta bituberculatus Ambrose and Kumaraswami	TR*	SB	SC	-	-	AL	-
130. NeovillanovwMS macrotrichiatus Ambrose and Vennison	TR*	SB	SC	-	•	AL	-
131. Occamus typicus Distant	TR*	-	C	-	-	AL	-
132. Panthous bimaculatus Distant	TR*	-	C	-	-	AL	-
133. Platerus bhavanii Livingstone and Ravichandran	TR*	-	C	-	-	AL	-
134. Platerus pilcheri Distant	-	-	C	-	-	AL	-
135. Platerus Sp.	-	-	C	-	-	AL	-
136. Polididus armatissimus (Stal)	AE,LA,SA, TR	BS,LR,SB	S	-	-	AL	GL

137. *P.brevispina* Livingstone and Ravichandran	AE,SJ,TR	BS,LR,SB	C	-	-	AL	
138.*Rhaphidosoma atkinsoni* Bergroth*	AE,SA,SJ, TR	BS,LR,SB, TM	S	-	-	AT	GL
139. *R.madukaraiensis* Ravichandran and Livingstone	SA**	SR,TM	S	-	-	AT	-
140. *R.tuberculatum* Distant	SA**	SB,TM	S	-	-	AT	-
141. *Rhaphdisoma* Sp.	SA,SJ	BS	S	-	-	AT	LS
142. *Rhnphdiaomn* Sp.	SA**	HS.SR	S	-	-	AT	-
143. *Rhaphdisoma* Sp.	SA**	BS	S	-	-	AL	-
144. *Rihirbus trichantericus* Stal	TR*	-	C	-	-	AL	-
144. *a) (var) sanguinosus*	-	-	C	-	-	AL	-
144. *b) (var) nigar*	-	-	C	-	-	AL	-
145. Rihirbus Sp.	TR*	-	C	-	-	AL	-
146. *Rhynocoris costalis* (Stal)	-	-	C	-	-	AL	-
147. *Rhynocorisfriscipes (*Tabricius*)**	AE,SA,SJ, TR	BS,SB,	C	-	-	AL	GL •
148. *R. kumarii* Ambrose and Livingstone*	AE,SA,SJ. TR	AR,DS,SO	C	-	-	AL	GL
149. *R. longifrons* (Stal)	AE,SA,SJ	BS	C	-	-	AL	GL
150. *R.maginatus (*Fabricius*)**	AE,SA,SJ	TR,BS	C	-	-	AL	GL
151. *R.marginellus* (Fabricius*)**	SA**	NS	SC	-	-	AL	GL
152. *R.tristicolor* (Reuter)	-	-	SC	-	-	AL	'-
153. *Rhynocoris* Sp.	TR*	BS.LR	C	-	-	AL	-
154. *Rhynocoris* Sp.	SA**	BS	C	-	-	AL	-
155. *Rhynocoris* Sp.	TR*	BS,LR	C	-	-	AL	GL
156. *Rhynocoris* Sp.	LA	-	SC	-	-	AL	-
157. *Rhynocoris* Sp.	SA**	BS	SC	-	-	AL	-
158. *Rhynocoris* Sp.	SJ***	BS	C	-	-	AL	-
159. *Scipinia horrida* (Stal)	SJ,TR	SB,LR	SC	-	-	AL	GL
160. *Serendiba pimdaluoyae* Distant	TR*	-	SC	-	-	AL	-
161. *Sp.hedanolestes annulipes* Distant	-	-	SC	-	-	AL	-
162. *S.aurescens* Distant*	TR*	AR,SB	SC	-	-	AL	GL

163. *S.bicolourous* Livingstone and Ravichandran	TR*	SB	SC	-	-	AL	-
164. *S. Dives* Distant*	TR*	AR,SR	SC	-	-	AI.	01.
165. *S. fratercuhus* Bergroth	SJ***	SB.	SC	-	-	AL	-.
166. *S. himalayensis* (Distant)*	TR*	AR,SB	SC	-	-	AL	GL
167. *S. indicus* Reuter	TR*	SB	SC	-	-	AL	-
168. *S.minusculus* (Bergroth)*	SJ,TR	AR,SB	SC	-	-	AL	GL
169. *S.nigrocephala* Livingstone and Ravichandran	TR*	SB	SC	-	-	AL	-
170. *S.pubinotum* (Renter)*	SJ,TR	AR.SB	SC	-	-	AL	GL
171. *S.pulchriventris* (Stal)	TR*	SB	SC	'-	-	AL	-
172. *S.signatus* (Distant)	AE,SJ,TR	SB	SC	-	-	AL	GL
173. *S.stigmatellus* Distant	SJ***	SB	SC	-	-	AL	-
174. *S.trichrous* Stal	-		SC	•	-	AL	-
175. *S.variabilis* Distant	TR*	SB	SC	-	-	AL	-
176. *Sp.hedanolestes* Sp.	TR*	AR,SB	SC	-	-	AL	GL
177. *Sp.hedanolestes* Sp.	SJ***	SB	SC	-	-	AL	GL
178. *Sycanus affinis* Renter*	TR*	L.R.SR	SC	-	-	AT.	GI,
179. *S.albofascialus* Bergroth	LA,TR	-	SC	-	-	AL	-
180. *S ater* (Wolff)	TR*	LR,SB	SC	-	-	AL	GL
181. *S. collaris* (Fabricius)	TR*	BK	SC	-	-	AL	-
182. *S.croceovittatus* Dohm	-	-	SC	-	-	AL	-
183. *S.giilbanns* Distant	TR*	SB	SC	-	-	AL	-
184. *S. indagator* Stal	LA, TR	UK	SC	-	-	AL	UL
185. *S.pyrhomelas* (Walker)*	TR*	BK,LR,SB	SC	-	-	AL	GL
186. *S.reclinatus* (Dohm)*	TR*	BK,SB	SC	-	-	AL	GL
187. *S.versicolor* (Dohm)*	TR*	RK,SR	SC	-	-	AI.	GI.
188. *Sycanus* Sp.	TR*	BFV,SB	SC	-	-	AL	GL
189. *Sycanus* Sp.	TR*	LR,SB	SC	-	-	AL	GL
190. *Velinus anmulatus* Distant	-	-	SC	-	-	AL	-
191. *V.castaneiis* Distant	-	-	SC	-	-	AL	-
192. *Vesbius purpureus* (Thunberg)	-	-	SC	-	-	AL	-

193. *V.sanffiinosus* Stal	AE,TR	SB	SC	-	-	AL	GL
194. *Villanovanus dichroiis* (Stal)	-	-	SC	-	-	AL	-
195. *Villanovamis* Sp.	-	-	SC	-	-	AL	-
VII. HOLOPTILINAE							
196. *Holoptilus fasciatus* Reuter	LA,SJ	-	S	-	-	AL	GL
197. *H.melanospilus* (Walker)	AE,.SL,TR	BS,LR	S	-	-	AL	GL
VIII. PEIRATINAE							
198. *Androclus pictus* (Herrich-Schaeffer)	-	-	AC	+	+	AL	-
199. *Calammrus brevipennis* (Serville)*	AE.SA.SJ	BS.CR	AC	+	+	BR	LS
200. *Cleptocoris atromaculatus* Stal	LA,SA,SJ	BS	AC	+	+	AL	-
201. *C.lepturoides* (Wolff)	AE,LA	BS	AC	+	+	AL	-
202. *Ectomocoris apimaculatus* Distant	-	-	AC	+	+	AL	-
203. *E.atrox* (Stal)	LA	-	AC	+	+	AL	LS
204. *E. biguttatus* Schouteden	-	-	AC	+	+	AL	-
205. *E. cordatus* (Wolff)	AE,LA	BS	AC	+	+	AL	-
206. *E.cordiger* Stal	AE,LA,SA	BS	AC	+	+	AL	-
207. *E.elegans* (Fabricius)	LA	-	AC	+	+	AL	-
208. *E.erebus* (Distant)	TR*	BS	AC	+	+	BR	-
209. *E.flavomaculatus* Stal	-	-	AC	+	+	AL	-
210. *E. gangeticus* (Bergroth)	AE,SA,SJ	BS	AC	+	+	BR.	-
211. *E. horridus* (Kirby)	TR*	BK,BS	AC	+	+	AL	-
212. *E. nigrochripes* Murugan and Livingstone	AE,SA,SJ, TR	BS	AC	+	+	BR	-
213. *E. ochropeterus* Stal	SJ***	BS	AC	+	+	AL	-
214. *E. quadirguttatus* (Fabricius)	AE,LA,SA, TR	BS,LR	AC	•	•	AL	LS
215. *E. simulans* (Distant)	-	-	AC	+	+	AL	-
216. *E. tibialis* (Distant)	AE,LA,SA, SJ,TR	BS.LR	AC	+	+	PO	LS
217. *E. tuberculatum* Livingstone and Murugan	AE,SA,SJ	BS	AC	+	+	AL	-
218. *E. vishnu* (Distant)	TR*	BS	AC	+	+	SD	LS
219. *E. xaveirei* Vennison and Ambrose*	TR*	BS	AC	+	+	PO	LS

220. *Ectomocoris* Sp.	LA	-	AC	+	+	AL	LS
221. *Ectomocoris* Sp.	LA	-	AC	4	+	BK	-
222. *Ectomocoris* Sp.	LA	-	AC	+	+	SD	-
223. *Ectomocoris* Sp.	LA	-	AC	+	+	AL	-
224. *Ectomocoris* Sp.	SA**	BS	AC	+	+	AL	LS
225. *Ectomocoris* Sp.	TR*	-	AC	+	+	AL	-
226. *Lestomerus affinis* Serville	AE,LA,SA, SJ,TR	UK,BS	AC	+	+	SD	LS
227. *L. sanctus Fabricius*	SA**	-	AC	^	+	AL	-
228. *Phalantus* Sp.	SA**	-	AC	+	+	AL	LS
229. *Phalantus* Sp.	-	-	AC	+	+	AL	-
230.*Peirates bicolor* Distant	LA	-	AC	(	+	AL	LS
231. *P. flavipes* (Walker)	-	-	AC	+	+	AL	-
232. *P. mundulus* Stal	-	-	AC	+	+	AL	-
233. *P. punctum* (Fubrivius)	AE,SA	BS	AC	+	+	AL	-
234. *P.sanctus* Fabricius	SA**	-	AC	+	+	AL	-
235. *P. unipunctatus* Livingstone and Murugan	AE.LA	BS	AC	+	+	AL	-
236.-*Peirates* Sp.	SJ***	BS	AC	+	+	AL	-
237. *Peirates* Sp.	SA**	BS	AC	+	+	AL	-
238. *Peirates* Sp.	TR*	-	AC	+	+	AL	-
239. *Sirtheneaflavipes* (Stal)	AE,LA,SA	BS	AC	+	+	AL	LS
240. *S.nigripes Murugan and Livingstone*	LA,SA	BS	AC	+	+	AL	-
241. *Sp.ilodermus quadrinotatus* (Fabricius)	AE,LA	BS,LR	AC	+	+	AL	-
IX. PHYSODERINAE							
242. *Physoderes impexa* (Distant)	-	-	AC	+	+	AL	-
X. REDUVIINAE							
243. *AcanthaSp.is alagirensis* Murugan and Livingstone	TR*	BS	AC	+	+	AL	-
244. *A. angularis* Stal	TR*	BS	AC	+	+	AL	-

245. A. *apicata* Distant	LA,SA,SJ	BK,BS	AC	+	+	AL	-
246.A.*biguttula* Stal	SA**	-	AC	+	+	AL	-
247. A. *bistillata* Stal	SA**	BS,CR	AC	+	+	AL	LS
248. A. *bambayensis* Distant	-	-	AC	+	+	AL	-
249.A.*carmata* Murugan and Livingstone	SJ***	BS	AC	+	+	AT	-
250. A. *concinnula* Stal	-	-	AC	+	+	AL	-
25l. A. *flavipes* Stal	LA,SA	S	AC	+	+	AL	-
252. A. *flavipes* (Dallas)	-	-	AC	+	+	AL	-
253. A. *helluo* Stal	-	-	AC	+	+	AL	-
254. A. *gulo* Stal	-	-	AC	+	+	AL	-
255.A. *lineatipes* Reuter	SJ***	BS	AC	+	+	AL	-
256. A. *Livingstone* Vennison and Ambrose	TR*	BK4.R	AC	+	+	AL	LS
257. A.*lutipes* Walker	-	-	AC	+	+	AL	-
258. A. *maculata* Distant	-	-	AC	+	+	AL	-
259. A. *micrographa* Walker	TR*	-	AC	+	+	AL	-
260. A. *minutum* Livingstone and Murugan	AE,SA	BS	AC	+	+	AT	-
26l.A.*nigricans* Livingstone and Murugan	TR*	BKJLR	AC	+ "	+	MR	-
262.A.*nigripes* Livingstone and Murugan	TR*	BS	AC	+	+	MR	-
263. A. *pedestris* (Stal)	AE.SA.SJ, TR	BSJM	AC	+	+	MR	LS
264. A.*philomanmariae* Vennison and Ambrose	SJ***	BS	AC	+	+	AL	LS
265. A. *quinquespinosa* (Fabricius*)	AE,LA,SA, SJ	BS,CR,TM	AC	+	+	AL	LS
266.A. *rama* Distant	AE,SA,SJ, TR	BK	AC	+	+	AL	LS
267.A.*rugulosa* Stal	LA,SA,SJ	BK.	AC	+	+	AL	-
268. A.*sexguttata* (Fabricius)	AE,SA,SJ, TR	BK	AC	+	+	AL	-
269.A.*siruvanii* Livingstone and Murugan	TR*	BK	AC	+	+	AT	-
270. A.*siva* (Distant)	AE,LA,5A, SJ.TR	BK,B5	AC	+	+	AL	L5
271.A.*subrufa* Distant*	SA,TR	BS	AC	+	+	AL	LS
272.A.*tergemina Bunneister*	AE,SA,SJ, TR	BK	AC	+	+	AL	

273. *A.trimaculata* Reuter	AE,SA,SJ, TR	BK	AC	+	+	AL	-
274. *A.zebraica* Distant	SA,SJ	BS,TM	AC	+	+	AL	-
275. *Acanthaspis Sp.*	SA,SJ	BS	AC	+	+	AT	LS
276. *Acanthaspis* Sp.	SJ***	BS	AC	+	+	AT	-
277. *Acanthaspis* Sp.	TR*	BS	AC	h	+	AL	-
278. *Acanthaspis* Sp.	SA*	BS	AC	+	+	AT	LS
279. *Acanthaspis* Sp.	SA**	BS	AC	+	+	AL	LS
280. *Acanthaspis* Sp.	SA,TR	BS	AC	+	+	AL	LS
281. *Acanthaspis* Sp.	TR**	BS	AC	+	+	MR	LS
282. *Acanthaspis* Sp.	BS***	BS	AC	+	+	MR	-
283. *Alloeocranum quadrisignatum* (Reuter)*	SJ***	BS,LR	AC	+	+	MR	LS
284. *Apechtia mesopyrrha* Reuter	TR*	BK	AC	+	+	AL	-
285. *Edocla heberii* Murugan and Livingstone	SJ***	BS	AC	+	+	AL	-
286. *E. maculatus* Murugan and Livingstone	SJ,TR	BS	AC	+	+	SD	-
287. *E.punctatum* Murugan and Livingstone	TR*	BS	AC	+	+	AL	-
288. *E.slateri (Stal)*	AE,SA,SJ, TR	BS.LR	AC	+	+	SD	GL
289. *Edocla* Sp.	TR*	-	AC	+	+	AL	-
290. *Empyrocorts annulata* Distant	TR*	LR	AC	+	+	SD	GL
291. *E. pelia* Distant	TR*	BS.LR	AC	+	+	SD	GL
292. *Mesacanthaspts kovatensis* Livingstone and Murugan	AE,SA	BS	AC	+	+	AT	-
293. *Neocanithaspis maculates* Murugan and Livingstone	LA,SA	-	AC	+	+	AL	-
294. *Paralenaeus* Sp.	SJ,TR	BS.LR	AC	+	+	AL	-
295. *Pasira perpusilla (Walker)**	AE,LA,SA, SJ	BS	AC	+	+	AL	LS
296. *Pasira* Sp.	SA**	-	AC	+	+	AL	-
297. *Pasiropsis nigerrima* Bergroth	SA.SJ	BS	AC	+	+	AL	-
298. *Reduvius delicatula* Distant	SA,SJ	BS	AC	+	+	AL	-
299. *Reduvius* Sp.	SJ***	BS	AC	++	+	AL	-
300. *Sminthocoris fuscipennis* Stal	TR*	BK,LR	AC	+	+	AL	-
301. *Stesiochorus* Sp.	-	-	AC	+	+	AL	-
302. *Velitra neelai* Murugan and Livingstone	TR*	BK	AC	+	+	AL	-
303. *V.sinensis (Walker)*	AE,LA,SA, SJ,TR	BK,LR	AC	+	+	AL	LS

XI. SAICINAE							
304. *Gallobelgicus typicus* Distant	LA	-	SC	-	•	AL	-
305. *Polytoxus femoralis* Distant	AK,LA,SA	HS,LR,SR	SC	+	+	AT	-
306. *P. fuscovittatus (*Stal)	AE,LA,TR	SB	SC	+	+	AL	
307. *P. maculanis* Distant	AE.LA	SB	SC	-	-	AL	-
308. *P. pallescens* Distant	SA**	SB	SC	-	-	AL	-
309. *Polytoxus* Sp.	SA**	I.R	SC	-	-	Al.	-
310. *Polytoxus* Sp.	-	-	SC	-	-	AL	-
XII. SALYAVATINAE							
311. *Lisarda annulosa* Stal	SA,SJ,TR	BL,LR	SC	+	+	AL	LS
312. *L. longiSp.ina* Distant	TR*	HS,TR	SC	+	+	Al.	I.S
313. *L.recurrva* Distant	-	-	SC	+	+	AL	-
314. *Nudiscutella fronstispina* Murugan and Livingstone	AE,SA,SJ, TR	BS	SC	+	+	AT	-
315. *Paralisarda* Sp.	SA**	LR	SC	+	+	MR	LS
316. *Paratisarda* Sp.	SA,SJ	LR	SC	+	+	AT	LS
317. *Paralisarda* Sp.	SA**	LR	SC	+	+	AT	LS
318. *Petalocheirus brachialis (*Stal)	LA,SA,SJ, TR	BRJ.R	SC	+	+	AL	LS
319. *P. burmanus* Distant	SR***	EK,BS,LR	SC	+	+	AL	-
320. *P.malayus* Stal	TR*	-	SC	+	+	AL	-
321. *Valentia apetala (*Vuillefroy)	-	-	-	-	-	AL	-
XIII. STENOPODAINAE							
322. *Aulacogenia errabunda (*Distant)	TR*	-	SC	-	-	AL	-
323. *A. corniculata* Stal	AE, LA	-	SC	-	-	AL	-
324. *Bardesanes sericenolatus* Livingstone and Ravichandran	AE	BS	SC	-	-	AL	-
325. *Canthesancus gulo* Stal	TR*	-	SC	-	-	AL	-
326. *C.helluo* Stal	-	-	SC	+	+	AL	-
327, *C.picticollis* Stal	TR*	SB	SC	+	+	AL	-
328. *Caunus farinator* Reuter	AE,LA	-	SC	-	-	AL	-
329. *Caurrus* Sp.	LA	-	SC	-	-	AL	LS
330. *Harpagochares typicus* Distant	-	-	SC	'	-	AL	-

331. *Hemisastrapada gandhigramensis* Livingstone and Ravichandran	SJ,TR	SB	SC	-	-	AL	-
332. *Oncocephalus anniei* Ambrose and Vennison	SJ***	BS,LR	SC	-	-	AL	LS
333. *O.annulipes (Stal)*	AE,LA,SA, SJ	BS.LR	SC	-	-	AL	LS
334. *O.aterrimus* Distant	AE,LA,SA	-	SC	-	-	AL	-
335. *O. bipunctatus* Livingstone and Ravichandran	LA,SJ	-	SC	-	-	AL	-
336. *0.chamundcus* Livingstone and Ravichandran	AE	-	SC	-	-	AT	-
337. *O.cingalensis* Walker	AE,LA	-	SC	-	-	AL	-
338. *O.funeralis* Distant	-	-	SC	-	-	AL	-
339. *O. impudicus* Reuter	AE,LA	-	SC	-	-	AL	-
340. *O. klugi* Distant	AE,LA,SA	BS.LR	SC	-	-	AL	LS
341. *O. lineosus* Distant	-		SC	-	-	AL	-
342. *O.micropterus* Homth	SA**	BS,LR	SC	-	-	MR	-
343. *O.modcstus* Reuter	AE,LA,SA	BS,LR	SC	-	-	AL	LS
344. *O.morosus* Distant	TR*	BS4.R	SC	-	-	BR	LS
345.0.naboides Walker	-	-	SC	-	-	AL	-
346. *O. nigrovittatus* Distant	-	-	SC	-	-	AL	-
347. *O.notatus (*Klug*)*	AE,LA,SA, SJ,TR	LR	SC	-	-	AL	-
348. *O.schioedtei* Reuter	AE.LA,SA	-	SC	-	-	AL	-
349. *O.yashpalii* Livingstone and Ravichandran	LA,SJ	-	SC	-	-	AI.	-
350. *Oncocephalus* Sp.	SA**	BS,LR	SC	-	-	AL	-
351. *Oncocephalus* Sp.	TR*	-	SC	-	-	AL	-
352. *Oncocephalus* Sp.	SA**	-	SC	-	-	AL	-
353 *Pygolampis fovea* Stal	AE,SA	-	SC	-	-	AL	-
354. *P. unicolor* Walker	AE	LR	SC	-	-	AL	-
355. *Pygolampis* Sp.	-	-	SC	-	-	AL	-
356. *Sastrapada baerenspprunKi (Stal)*	AE,LA,SA	BS,LR	SC	-	-	AL	-
357. *S.elongata* Livingstone and Ravichandran	AE.SA	-	SC	-	-	AL	-
358. *Staccia diluta (Stal)*	AE,LA,SA	BS.LR	SC	-	-	AL	-

359. *Thodelmus falleni* Stal	TR*	-	SC	-	-	AL	-
XIV. TRIATOMINAE							
360. *Linshcostms camifcx* Distant	H	CR	S	-	-	AL	LS
361. *L. confumus* Ghauri	LA.SA	BS,CR	S	+	+	AL	-
362. *L.costalis* Ghauri	LA,SA	BS,CR	S	+	+	AL	-
363. *Linshcosteus* Sp.	SJ***	BS,CR	S	-	-	AL	LS
364. *Linshcosteus* Sp.**	H	CR	S	-	-	AL	LS
365. *Triatoma rubrofasciala* ** DeGeer	H.LA	CR	S	-	-	AL	LS
XV. TRIBELOCEPHALINAE							
366. *Ophistoplatys majusculus* Distant	-	-	S	-	-	AL	-
367. *O.tenebrarius*	-	-	C	-	-	AL	-
368. *Tribelocephala indica* (Walker)	SA,TR	BS,LR	SC	-	-	AL	-
369. *T.orientalis* Schouteden	TR*	BS	SC	-	-	AL	-
370. *T. uppasii* Livingstone and Ravichandran	TR*	BS	SC	-	-	AL	-

1.	Habitat	AE - agroecosystem, LA - light attracted, SA - semiarid zone, SJ - scrub jungle, TR - tropical rainforest
2.	Microhabitat	AR - aerial, BK. - bark, BS - boulders, CR - crevices, H - human dwellings, SB - shrubs, LR - litter, TM-termitorium
3.	Rostam	AC - acutely curved, C - curved, S - straight, SC - slightly curved :
4.	Tribal pad	(+) present, (-) absent, (.*) rudimentary
5.	Wing	AL - alate, AT – apterous, BR – brachypterous, MR - micropterous, PO - polymorhphic SD - sexually dimorphic, (-) not known
6.	Eggs	GL - glued, LS - loose ; biological control agent, ** : domestic pest

TR - t, SJ - ?, SA - u, - Endemic species of tropical rainforest, scrub jungle and semiarid zone ecosystem.

Table 2
Microhabitat And Habitatwise Distribution And Diversity Of Indian Assassin Bugs

Subfamily	Total no. of species	Exclusive microhabitats								Exclusive habitats							
		A R	BK	BS	CR	LR	SB	*	-	A E	H	LA	SA	SJ	TR	*	-
Apiomerinae	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
Centrocnemmąe	4	-	-	-	-	-	-	1	3	-	-	-	-	-	-	1	3
Ectmoderinae	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
Ectrichodiinae	34	-	3	19	-	-	-	9	3	2	-	-	4	2	7	17	2
Emesinae	19	2	-	3	-	-	1	6	7	2	-	1	-	1	7	6	2
Harpactorinae	136	-	3	13	-	1	24	44	51	-	-	2	7	8	61	29	29
Holoptilinae	2	-	-	-	-	-	-	1	1	-	-	-	-	-	-	2	-
Peiratinae	44	-	-	18	-	-	-	6	20	-	-	7	4	2	7	16	8
Physoderinae	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
Reduviinae	61	-	8	26	-	1	-	14	12	-	-	-	5	8	16	24	8
Saicinae	7	-	-	-	-	1	3	1	2	-	-	1	2	-	-	3	1
Salyavatinae	11	-	-	-	-	3	-	5	3	-	-	-	1	1	2	5	2
Stenopodamae	38	-	-	1	-	2	2	9	24	3	-	1	3	1	6	17	7
Triatominae	6	-	-	-	3	-	-	3	-	-	2	-	-	1	-	3	-
Tribelocephalinae	5	-	-	2	-	-	-	1	2		—	-	-	-	2	1	2
Total	370	2	14	82	3	8	30	99	132	7	2	12	26	24	108	124	67

Habital : AE - agroecosystem, LA - light attracted, SA - semiarid zone, SJ - scrub jungle, TR - tropical rainforest, H - human dwellings.

Microhabitat : AR - aerial, BK - bark, BS - boulders. CR - crevices, SB - shrubs. LR - litter.

* Other microhabitats or liabitats and their respective combination not known

Tables 3
Morphological and Behavioural Characteristic Wise Distribution and Diversity of Indian Assassin Bugs

Subfamily		Rostrum				Tibial pad			Wing						Eggs		
	Total no. of species	AC	C	SC	S	F& M	F	R	AL	B R	MR	AT	PO	SD	GL	LS	UK
Apiomcrinac	1				1	-	-	-	1	-	-	-	-	-	-	-	1
Centrocnenunae	4	3	-	1	-	4	-	-	4	—	-	- •	-	-	-	1	3
Ectinodennae	1	-	1	-	-	1	-	-	1	-	~	-	-	-	-	-	1
Ectrichodiinae	34	3	3U	1		33	-	1	18			12	1	3	2	8	24
Emesinae	19	-		19	-	-	-	-	14	-	-	5	-	-	-	1	18
Harpactorinae	136		23	102	11	-	-	-	131			5			51	1	84
Holoptilinae.	2	-	-	-	2	-	-	-	2	-	-	-	-	-	2	-	-
Peiratinae	44	44	-	-	-	43	1	-	34	5			2	3		12	32
Physoderinae	1	1	-	-	-	1	-	-	1	-	-	-	-	-	-	-	1
Reduviinae	61	61	-	-	-	61	-	-	44	-	6	7	-	4	3	16	42
Saicmae	7	-	-	7	-	3	-	-	6	-	-	1	-	-	-	-	6
Salyavatinae	11	-	-	11	-	11	-	-	7	-	1	3	-	-	-	6	5
Slenopodainae	38	-	-	38	-	2 -	-	-	35	1	1	1	-	-	-	6	32
Triatominae	6	-	-	-	6	2	-	-	6	-	-	-	-	-	-	4	2
Tribelocephalinae	5	1	3	1	-	-	-	-	5	-	-	-	-	-	-	-	5
Total	370	113	57	180	20	161	1	1	309	6	8	34	3	10	58	56	256

Rostrum : AC - acutely curved, C - curved, S - straight, SC - slightly curved

Tibial pad : (+) present, (-) absent, (*) rudimentary

Wing : AL - alate, AT - apterous, BR - brachypterous, MR - micropterous, PO – polymorhphic; SD = sexually dimorphic, (-) not known

Eggs : GL - glued, LS - loose. UK - unknown.

Fig. 1. Pie diagram showing the microhabitatwise distribution and diversity of Indian assaassin bugs

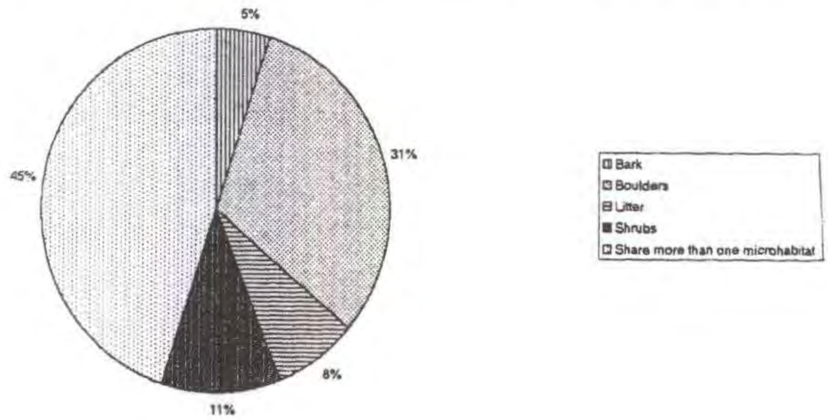


Fig. 2. Pie diagram showing the habitatwise distribution and diversity of Indian assaassin bugs

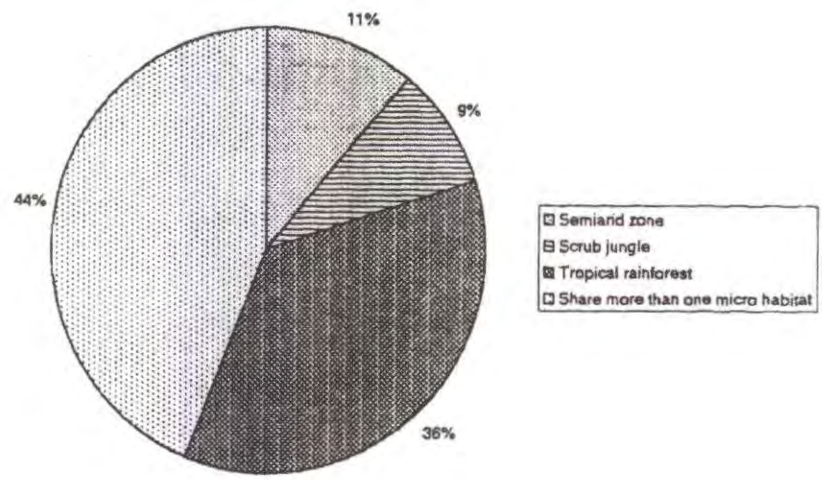


Fig. 3. Pie diagram showing the diversity of rostrum in Indian assaassin bugs

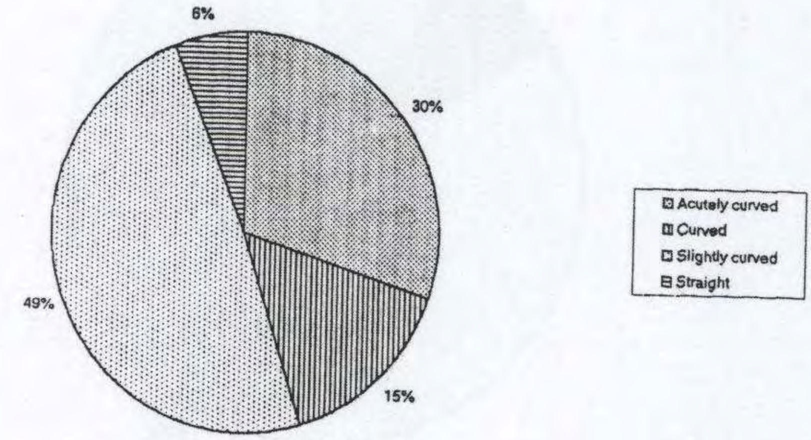


Fig. 4. Pie diagram showing the diversity of tibialpad in Indian assaassin bugs

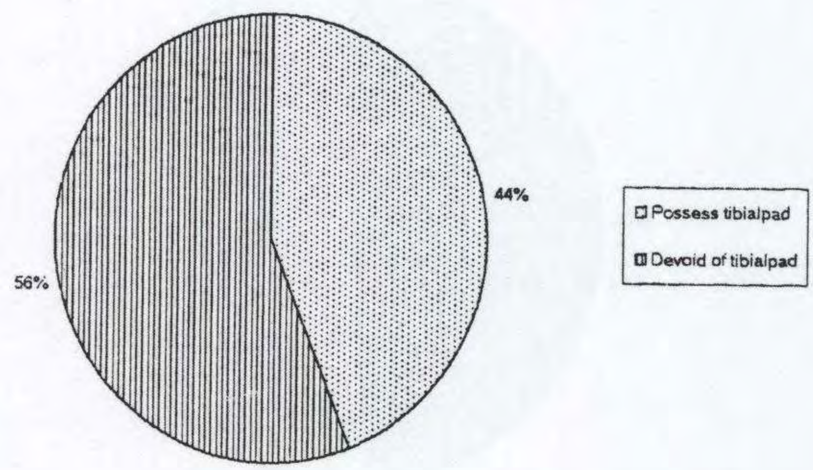


Fig. 5. Pie diagram showing the diversity of wings in Indian assaassin bugs

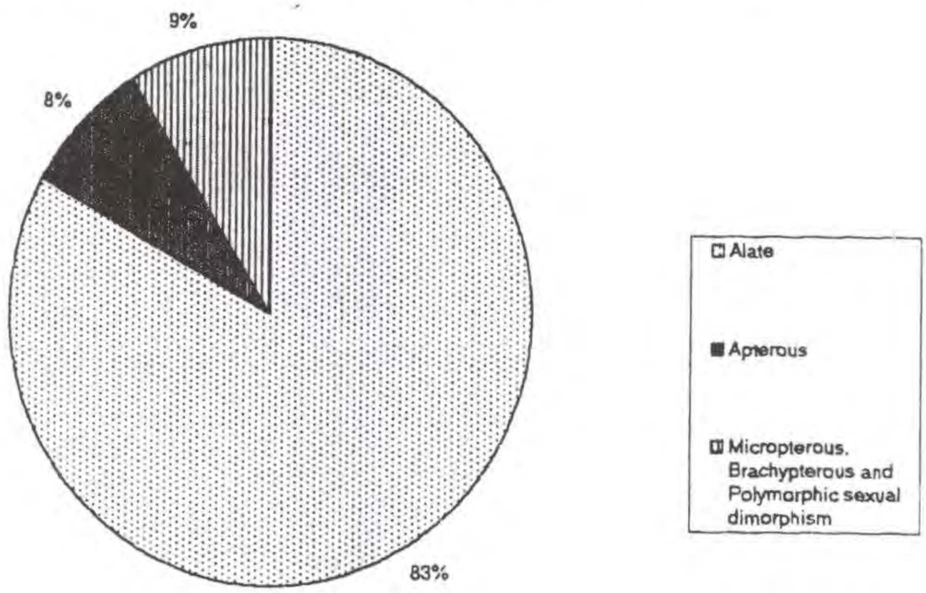
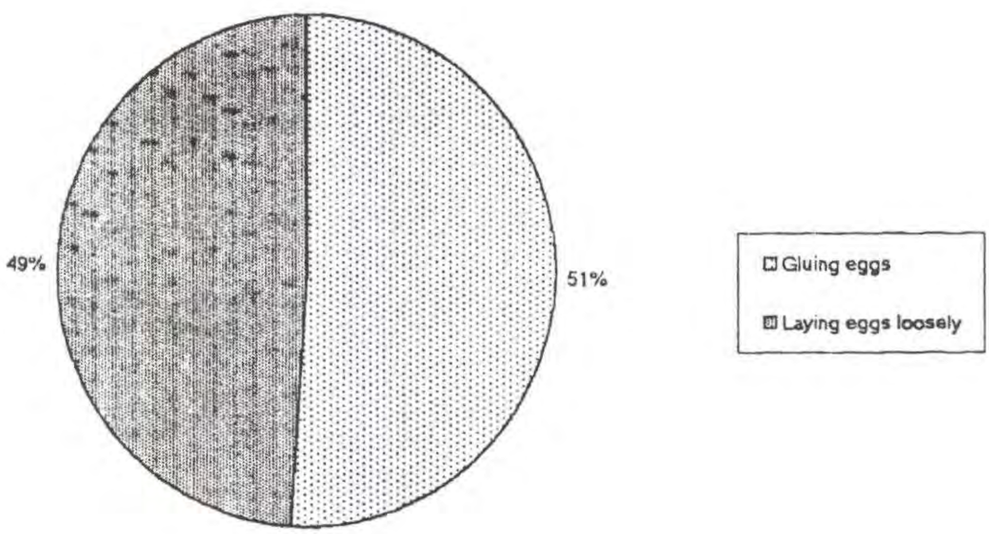


Fig. 6. Pie diagram showing the diversity of egg laying in Indian assaassin bugs



Chapter 5

A REVIEW OF LITERATURE ON THE DIPLOPODS OF THE FAMILIES HARPAGOPHORIDAE AND PARADOXOSOMATIDAE OF INDIA

Kubra Bano

Abstract

This paper presents a review of systemetic studies of the Indian Diplopods with a special reference to the two families Harpagophoridae (Order Spirostriptida) and Paradoxosomatidae (Order: Polydesnida). Among the Indian diplopods the distribution, diversity and abundance of speices within these two families are very large in India and they are reported to be the endemic fauna. A total of 53 species of Harpagophorids ("strictp semsp") belonging to 11 genera and 57 species of Paradoxosomatid millipedes belonging to 24 genera have been reported in India.

Introduction

The class Diplopoda represents one of the largest classes of the animal kingdom and is the third largest class of the phylum Arthropoda (Goovatch *et al* 1995). It comprises of 80,000 species approximately (Hoffman 1980, Goovatch *et al* 1995), of which only 10-15% have been studied and described so far (Goovatch 1997). Diplopods are largely mesophyllic and hygrophyllic, hence their taxonomic richness, diversity and life forms are restricted to tropical and subtropical regions of the world. They are primarily stratobiont with a very few being caverniculous and geobionts. Extreme habitats such as deserts and tundra are completely devoid of them (Golovatch 1987). Since these animals are very slow in their movements, cryptic in their habit, and have limited power of dispersal, every patch of land has different fauna of its own and it is so with tropical forests too. Millipedes with their long life cycles, and large number of stadia with frequent molts have limited power of dispersal. This results in high degree of speciation and endemism (Hopkin and Read 1992), which is very evident with the Indian fauna.

Diplopods are the common and conspicuous fauna of the upper soils and litter layers of the tropical, subtropical and temperate forest regions of the world. About 2500 genera are reported from all over the world, which are grouped into 160 families, 16 orders and 3 subclasses (Golovatch 1997). Most of the 10,000 described known species are known most of them are from European countries, and are probably 1/5th of the actual number of living species (Hoffman 1990). The research work on diplopods is very limited, and has received very little attention from systematists and the biologists. Perhaps their obscure nature might not have evinced interest among the zoologists and entomologists and thus there is a lack of expertise on the subject. The taxonomy of this group remains at alpha stage and the biology is at infant stage, excepting for a small group of North European fauna (Hoffman 1990). However, the investigations that have been carried out on the taxon have revealed some biological peculiarities that are restricted exclusively to this group. The synecological role of millipedes in the soil-litter milieu is comparable to that of earthworms (Hoffman 1990). These animals, as soil communities and their role in biological decomposition require attention, investigations and documentation.

Distinguishing features of Diplopoda

The class Diplopoda may be defined as a group of terrestrial, tracheate, antennate, mandibulate, progoneate, oviparous and anamorphic arthropods, bearing eight jointed antennae, a plate like fused maxillae called "gnathochilarium" the floor of the buccal cavity, a pair of mandibles functioning as cutting jaws. Diplopods are herbivorous, usually cylindrical, hard crustaceous long bodied animals, with two pairs of legs on most of the body segments that correspond to the double nature of the segments or the diplosomites. Anterior few segments bear a single pair of legs, and last somite is devoid of legs, but ends with a telson. Most of the body somites laterally carry a pair of ozopores, the openings of the ozodenes or the defence glands. Some of these peculiarities distinguish them from other Arthropods.

Review of literature

Despite their large availability, the millipedes are least explored in tropical countries and more so in India. The systematic studies of Diplopoda, which were conducted by the European investigators, date back to the late 19^{th} and early 20^{th} centuries. Pocock (1892) was the pioneer myriapodologist who described a few species of the order Helminthomorpha and Oniscomorpha from the collections of Government Central Museum, Madras (now Chennai), and published a monograph on the pill millipedes of India, Ceylon and Burma (1899). Subsequently, Silvestri (1916) described 4 new species of Aulocobolus from India, a few millipedes of the order Oniscomorpha from Oriental region (Silvestri, 1917), 5 new subgenera of Pyragodesminae (Silvestri, 1920), some Indian and Malayan millipedes of the family Trachyiulidae, and synonymised the genus Caimbolopsis as Tmchywius (Silvestri, 1923) and also reported and described a cavemiculous millipede from Siju caves of Assam (Silvestri, 1924). Attems (1936) was the first to give an exhaustive report on the Indian diplopods. He devised the key for their identification, and reported Indian fauna comprising of 290 species belonging 92 genera. All the species were reported to be endemic to India. Of the 92 genera, 64 are endemic and the other 28 are found to occur outside India also. He described 62 new species and 15 new genera, and stated that the reported faunistic list is far from complete, and description of zoogeographic distribution at that point would not be valid. The reported Indian fauna comprised of great number of Sphearotherida, Glomeridesmida, Spirostreptida, Spirobolida, and Polydesmida.

Review of literature on the family Harpagophoridae

Attems is the father of Myriapodolgy in India. His extensive work on this subject is the only reliable source of literature even to this day. Verhoeff(1936) reported a few species of this family from India. Carl (1941) brought out a monograph viz. "Nematophora and Juliformia" on the millipede fauna of South Peninsular India and Ceylon in which he reported several genera and species of this family new to science. Attems (1942) revised generic nomenclatures of some Harpagophorid millipedes proposed by himself and also by Carl. He allocated the species that were reported under the genus *Thyropygus* from

India to different genera Viz *Phyllogainostreptus, Gnomognsithm, OrgMognaithus,* etc. after making careful studies of the collections. Krishnan (1968), the only Myriapodologist from India at that time, brought out a monograph on the single Genus *Thyropygus,* and described 10 species from South India, despite the fact that these species were allocated to different genera. This misrepresentation by Krishnan indicates that he could not lay his hands on the work of Attems (1941). Further, this genus has not been reported by any Myriapodologist from India. Demange (1968) and Hoffman (1975) have confirmed that the genus *Thyropygus* is an African genus, does not exist in India and has not been reported so far (Personal communication with the author), although there exists a close relationship between the Indian and African Fauna. In the wake of these findings, the earlier reports of occurrence of *Thyropygus* in India remain null and void. The extensive work of Demange (1968) included description with illustrations of several genera and species of Harpagophorid millipedes, along with key for their identification. His later works included a new species *Phyuogontofstreptus sihestris* from Sal forest, Madhya Pradesh (Demange, 1970), description of a new species P. *pocullifem* from south India, reallocation of *Thyropygus negotiosus* as *negotioms* (Demange, 1975), two new species *Cmlogonus palmatus* and *Orgsinognsithus janmdhsinam* (Demange, 1977a) and two species of *Cairlogonus,* viz. *C. chowdmeiM* and C. *eicifer* from south India, a new genus *Msardonms* (Demange, 1977), description of a new species C. *auricuilus* from Kamataka (Demange, 1983) and a new genus *Janardhananeptus* with a single new species J. *cannanorensis* from Kerala (Demange1989).

All the above listed literature of different scientists being either in French or in German language, their accessibility to other scientists including Indian scientists have been very limited leading to poor study of this group of Arthropods.

Hoffman (1977) dissociated the genus *Leptostreptus* from the family Harpagophoridae and created a new family Adiaphorostreptidae with a type genus *Adiaphorostreptus.* To this new family he assigned *L. caudatus* and *L. fuscus* from Ceylon and *L leviventer* from peninsular India. Hoffman and Burkhalter (1978) reported the genus *Gonoplectus* with five species from Assam and Darjeeling. Demange (1961) synonymised the genera *Thyroglutus* and *Gongylorrhus* reported by Attems (1936) as *Gonoplectus.* According to Hoffman and Burkhalter (1978) Harpagophorid fauna of peninsular India is still poorly known, but it appears to have affinity with that of the South African fauna.

After a lapse of two decades, Bano (1998) presented a taxonomic review of the family Harpagophoridae with a checklist of Indian species known till then, and added a note on the emendation of the genus *Thyropygus.* A key for the identification of the Indian genera of the family Harpagophoridae, and an illustrated key for identification of the millipedes of the orders of Indian Diplopoda are under publication with Bombay Natural History Society.

Review of literature on Paradoxosomatidae

Daday (1889) proposed the family Paradoxosomatidae under the order Polydesmida. Cook (1895) created another family Strongylosomatidae. Attems (1914) erected the family

Strongylosomidae and published his work in Das Tierreich (1937). Under the family Strongylosomidae, Attems (1936) described a large number of species and genera along with the key for their identification. His work formed the basis of research for other diplopodologists. Hoffman (1963) in his work on this group of millipedes of south East Asia remarked that the diversity and abundance of this group of millipedes are at its zenith in peninsular India and adjoining islands. After a lapse of three decades, Jeekel (1968) studied this group of millipedes, resurrected the nomenclature Paradoxosomatidae proposed by Daday (1889) and synonymised the names Strongylosomidae and Strongylosomatidae. He revised the entire family giving morphological details of taxonomic importance, created several taxons, and provided diagnostic characters at all taxon levels. He gave a list of Indian Paradoxosomatid millipedes with their generic characters and their taxonomic positions. Jeekel (1980) allocated the names of the two species *Orthomorpha coonorensis* and *Orthomorpha dentata*. Carl (1932) to two new genera *Parchondromorpha* and *Harpagomorpha* respectively. He created a new genus *Antichirogonus* and placed the two Indian species *Sundanina laevisulcata* and *Sundanina hirta* under this new genus. In the same paper, he presented the characteristics of the genera *Polydrepanum* and *Dasypharkis*. Golovatch (1983) reported 16 species of Paradoxosomtid millipedes of 13 genera from India. Of them, eight genera were new to India and to science. In 1984, he created a new genus *Substrongylosoma* for two related species S. *distinctum* and *S. falcatum* both from Darjeeling, and simultaneously erected, a monotypic-genus *Himalomorpha* for a sympatric sp. *Strongylosoma montigena,* and these three species were placed with in the tribe Strongylosomatini. In 1992 he reported *Kronopolites unicolor* from Assam and Darjeeling and assigned it to a new genus *Martensosoma.*

Golovatch and Martens (1996) reported a list of the fauna of millipedes from Himalayas including Indian species. Bano (1998) reported the distinguishing characteristics and systematics of Indian Paradoxosomatid millipedes with an updated checklist of the species of Paradoxosomatid millipedes known till then.

Review of literature as on today reveals that the Indian fauna consists of 11 orders, 19 families with 100-120 genera and about 500 species (Bano 1999). The reported number of species is definitely very much less than what must actually exist, and have remained unnoticed and undiscovered due to paucity of investigators.

With this basic knowledge on the subject, a study of diplopods was thought of. Among the 19 families reported, large species diversity was found with two families, the Harpagophoridae and Paradoxosomatidae, followed by Sphaerotheridae and Spirobolidae. To make a beginning in the study of systematics, the two families, Harpagophoridae and Paradoxosomatidae, were selected for the purpose of revision and updating. To explore the fauna brief surveys were conducted in the Western Ghats of peninsular India during the monsoon periods of 1994-1995. The millipedes collected were preserved, identified and described (1997). A baseline data on the taxonomic aspects and checklists of known species were presented (Bano 1998a,b).

From the collections made, twenty-four species of Harpagophoridae belonging to seven genera, viz. *Harpurostreptus, Carlogonus, Gnomognathus, Organognathus, Phyllogonostreptus and Humbertostreptus* were identified. *Humbertostreptus*, an African genus (Demange 1961), is reported for the first time from India. In addition, a millipede belonging to a new genus was also discovered, which is new to science and to India. The new genus is christened *Dharmastreptus* with a single species (Bano, report under preparation). Among the genera reported from India the genus, *Gonoplectus* is restricted to Northeast India, whereas the other genera are largely from peninsular India. The genera *Ktenostreptus and Fageostreptus* (Attems 1936) were lacking in the collections made by the author. This may be attributed to insufficient exploration or to incorrect identification of the earlier workers. Puttarudraih and Shastry (1954) reported *Ktenostreptus sp.* as a pest on cotton crop from Chitradurga. In the present survey, two species of *Mardonius* (Order Spirostreptida: Family Spirostreptidae) have been collected from the same region on vegetable crops.

From the family Paradoxosomatidae, 18 species belonging to seven genera, viz. *Chondronpha, Anoplodesmus,* Polydrepanum, *Orthmorpha, Streptogonopus, Paranedyopus* and *Oxidus* were recorded. Two new genera of Paradoxosomatidae have been discovered that are yet to be named. Two new species belonging to the genera *Polydrepanum* have been discovered and are to be named. The report reflects faunal diversity, microhabitat and distributions of millipedes of these two families (Bano, 1997).

From Himalayan region more than 200 species of diplopods are reported (Golovatch and Martens 1996), of which about 50 species of 21 genera and 14 families are from North East India.

A checklist of Harpagophorid millipedes of India presented by Bano (1998) contains 60 species, out of which 20 are listed under "*Incertae sedis*". This means about 40 species are definitely Harpagophorid. This demands a revised study on identification of these millipedes.

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Plate 2

Tranantula Spider : WII AV Library

Platacanthomys lasiurus : S.U. Saravana Kumar

Chapter 6

STATE OF THE ART KNOWLEDGE ON THE BUTTERFLIES OF NILGIRI BIOSPHERE RESERVE, INDIA

George Mathew and M. Mahesh Kumar

Introduction

India has a rich butterfly fauna comprising of 1501 species out of 16, 823 species recorded from all over the world (Gaonkar, 1996). Of the various butterfly habitats found in India, the Western Ghats is one of the most diversified areas containing a wide variety of species due to the typical eco-climatic and geographic features. In the Western Ghats, maximum diversity is observed in the Nilgiri Biosphere Reserve (NBR) region. Of 330 species recorded from the Western Ghats, 316 species have been reported from the NBR.

Review of studies on butterflies of India

Studies on Indian butterflies were initiated by Fabricius and Cramer as early as 1775. Faunistic explorations by subsequent workers like Horsfield (1828-29), Moore (1881), Marshall and de Niceville (1883), de Niceville (1886,1890), Moore and Swinhoe (1890-1913), Bingham (1905), Bell (1909-1927), Ormiston (1924), Evans (1932) and Yates (1935,1946) have contributed much to our knowledge of these insects

During 1939 to 1947, Talbot published two volumes on butterflies in the Fauna of British India series *viz*., Butterflies, Vol. I and Vol. II, respectively (Talbot, 1939, 1947). The Ist volume contained descriptions of 199 species belonging to Papilionidae (94 spp.) and Pieridae (105 spp.). Among papilionids, 18 species were from peninsular India with 5 species specifically recorded as from the Nilgiris. In the case of Pieridae, 37 species were from peninsular India which contained a species - *Pieris canidia canis* Evans - specifically recorded from the Nilgiris. The volume II covered the families Danaidae, Satyridae, Amathusiidae and Acraeidae (all are now included under Nymphalidae). It contained descriptions of 38 species of Danaidae (9 species from peninsular India with one species, *ie*., *Danaus nilgiriensis* (Moore) from the Nilgiris); 186 species of Satyridae (28 species from peninsular India with 7 species from the Nilgiris); 26 species of Amathusiidae (2 species from peninsular India) as well as 2 species of Acraeidae (1 species from peninsular India). "Butterflies of the Indian Region", published by Wynter-Blyth (1957) contained a detailed account of the ecology and

Table 1. Number of butterflies specifically recorded from south India and the Nilgiris.

Family	No. of butterflies recorded	
	S. India	Nilgiris
Danaidae	11	1
Satyridae	23	6
Amathusiidae	2	0
Nymphalidae	47	12
Erycinidae	3	0
Lycaenidae	88	20
Papilionidae	19	4
Pieridae	29	3
Hesperiidae	51	19
Total	**273**	**65**

biology of Indian butterflies with good coverage for species from the W. Ghats (Table 1). Recently, Gunathilagaraj *et al.* (1998) have produced a book on the butterflies of south India.

Butterflies of NBR

The most comprehensive study of butterflies of the Nilgiri hills was by Larsen (1987,1988) wherein he listed 299 species (indicating the endemic species) belonging to Papilionidae (19 endemic species), Pieridae (30 endemic species), Lycaenidae (91 endemic species), Nymphalidae (89 endemic species) and Hesperiidae (70 endemic species). He also updated the ecological data on various species based on his own observations. Gaonkar (1996), in his study on the butterflies of W. Ghats, consolidated available information listing 17 additional species from the Kerala, Tamil Nadu and Karnataka regions of the W.Ghats (Table 2).

Table 2. Butterflies of the Indian Region : W. Ghats and NBR

Families	No. of species recorded		
	Indian Region	**W. Ghats**	**NBR**
Papilionidae	107	19	19
Pieridae	109	33	30 (+1)
Nymphalidae	521	96	89 (+5)
Lycaenidae	443	101	91 (+8)
Hesperiidae	321	81	70 (+3)
Total	1501	330	299 (+17)

*Numbers in brackets are the additional species recorded by Gaonkar(1996) which were not included in Larsen (1987-88).

A list of butterflies added by Gaonkar (1996) is given in Table 3. In this work, he gave complete details of 330 species belonging to 166 genera present in this area. Based on their distribution and host plant association, he also recognized three biogeographical zones for the W. Ghats fauna. Of the three zones, the NBR, which formed the southern and central region, was found to sustain maximum number of species including several endemics. The occurrence of such large number of endemic species was found to be correlated with the high endemism shown by the flora of this region.

Table. 3. List of additional butterflies (Gaonkar, 1996) recorded from Kerala, Tamil Nadu and Karnataka parts of W. Ghats that are not covered by Larsen (1987-88).

Family	*Species*
Pieridae	*Eurema nilgiriensis*
Nymphalidae	*Parantirrhoea marshalli* *Mycalesis oculus* *Ypthima ypthimoides* *Phalanta alcippe* *Pantoporia sandaka*
Lycaenidae	*Logania distanti* *Tarucus indica* *Azanus uranus* *Udara singalensis* *Catochrysops panormus* *Arhopala bazaloides* *Arhopala atrax* *Apharitis lilacinus*
Hesperiidae	*Aeromachus pygmaeus* *Hyarotis microsticta* *Erionota thrax*

Endemic and protected species

The conservation value of any region depends on the extent of endemic and protected species present. From the NBR region, 48 endemic butterflies have been recorded (Larsen 1987, 1988).

With regard to the protected species, 41 species of butterflies recorded from NBR have protected status under the Wildlife (Protection) Act, 1972 (Anon.,1990). This include 8 species belonging to Schedule I, 26 species in Schedule II and 7 species in Schedule IV.

Lacunae in the existing information and proposed future course of action

Other than their aesthetic value, butterflies have important roles in the functioning of forest ecosystems. Because of their diversity, wide distribution, specificity to vegetation type, rapid response to perturbation, taxonomic tractability, statistically significant abundance and ease of sampling, they have been considered useful organisms to monitor environmental changes. The occurrence of a large number of rare and endangered species in the NBR indicates the prevailing specialised environmental conditions in this area that support these butterflies. Detailed studies on the bio-ecology of various species found in this region are necessary for adopting appropriate conservation strategies. Recently, some studies have been made on the habitat preferences of butterflies found in the Kerala part of W. Ghats (Mathew, 1990; Mathew

and Rahamathulla, 1993).

Since it is not possible to create existing ecological conditions elsewhere, studies involving both *in situ* and *ex situ* conservation also may be attempted. For this, species specific details covering biology, host plant preferences, ecological requirements *etc.*, of various species need to be generated. For *ex situ* conservation, prioritisation of species based on the ecological significance, aesthetic value and rarity is essential. It is also necessary to standardise techniques for mass rearing rare species for reintroduction in conservation programmes. Establishment of a captive breeding laboratory is essential for this purpose and KFRI has recently developed sufficient expertise in this area through assistance received from the Ministry of Environment and Forests, New Delhi. Creating public awareness for species conservation is all the more important for the success of such activities. A butterfly garden meant for *in situ* conservation and environmental education along with a captive breeding facility for helping in *ex situ* conservation programmes established at Peechi, have been found to be very successful and continued assistance for such activities is required.

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Chapter 7

AN OVERVIEW OF SPIDER DIVERSITY IN INDIA

Rajashekhar K P and Raghavendra N

- Introduction
- Review of literature on spiders
- International status
- Indian literature
- Spiders in Western Ghats
- Seasonal variation of spiders
- Recommendations
- References

Introduction

Due to an inherent drive for survival, the life forms have adapted and evolved. These adaptations are aimed at countering environmental challenges. As there can be alternate ways of adapting to a demand, life forms have evolved varied strategies. Various taxa arise due to such diverse approaches. Biodiversity refers to such variations in life forms. A group of individuals that have identical traits and are reproductively compatible constitute a species. Diversity also arises due to the fact that earth has a diverse geography. Based on geography, a classification of biomes has been formulated. The tropical humid rain forests host the most diverse and abundant biodiversity. Such tropical humid rain forests are seen confined to landmasses of the equatorial region. Due to unique geological formations and climate, some of the rain forests are also observed in south Asia in the Western Ghats of India, Northeast India and Myanmar. The climatic conditions here support a rich flora and consequently a diverse fauna.

Myers (1988) classified areas that are rich in endemic species and are threatened by human activity as "biodiversity hotspots". These are high priority terrestrial eco-regions for conservation. Myers *et al* (2000) reclassified the hotspots and identified eight "hottest hotspots". The Western Ghats/Sri Lanka region occupies the seventh place in this list. The recent "Global 200" classification by WWF ranks the Western Ghats at twentieth place among 200 ecologically sensitive regions. As the major threat to any biodiversity hotspot is the human intervention, Cincotta *et al* (2000) analysed the human population dynamics in biodiversity hotspots. The Western Ghats are the most threatened on this count as this region has the highest population density per sq. km (340 km^{-2}) among the hotspots and a positive growth rate.

A quick glance at the biological diversity reveals that arthropods are the most diverse group of organisms. The product of evolution over millions of years has yielded a diversity which is "biased". It has generated a very diverse group of arthropods and in particular, insects. Arthropods constitute 64.5% of the described species as compared to plants (14.3%), fungi (4.2%) and vertebrates (2.3%) (Anonymous 1995). The arachnids constitute the second largest class (7%) of documented arthropods and it is estimated that 8.3% of arthropods are arachnids. Thus arachnids rank second among arthropods. Arthropods comprise more than 900,000 described insect species and about 34,000 described spiders. The order Araneae of class arachnida consists of spiders. The suborders mesothelae and orthognatha consist of primitive spiders, and the suborder labidognatha includes the more recent spiders.

The significance of insects in ecology needs no emphasis. Spiders also have a very significant role to play in the ecology by being exclusively predatory (Wise, 1993) and thereby regulate insect populations. All spiders are venomous but only a few species are venomous enough to harm humans. However, the venom of some spiders is useful in study of neuromuscular and cardiac pharmacology. It is likely that spider

silk will be the material of the future as its silk is the toughest material known. The gene for the silk of *Nephila maculata* has been cloned and the spinning technology needs to be perfected. The coloration of spiders is varied and is paralleled only by insects (Oxford and Gillespie 1998). Spiders may also serve as biocontrol agents (Raghavendra 2001). Inspite of several applied values mentioned above, spiders have received cursory attention. In conservation efforts, often "charismatic" species like birds and mammals draw most attention and ecological significant groups like spiders are often neglected. Only tarantulas are included in Appendix II of CITES.

Review of literature on spiders

Despite the paucity of interest in spider fauna many good accounts on spider fauna are available and information on internet does provide an outline of the spider fauna in various regions. Conventionally, taxonomic accounts have been descriptive with anatomical details and at best provide hand-drawn illustrations. For a group like spiders, there is a need to document the fauna with colored illustrations, which will help easy identification.

International status

The distribution and diversity of spiders has drawn attention of field workers in different parts of the world. These are often restricted by political boundaries and therefore often appear as studies on spider fauna of individual countries. In an effort to popularize spider biology and educate the general public many authors have put in their efforts. Taylor (1999) provides a good and well-illustrated account of the diversity, beauty and intricacies of spiders. Another recent publication by the Discovery books (Anonymous 2000) illustrates spiders and some of the families of spiders. A compendium of the spider fauna of North America is provided in Vincent Roth's Field Guide (2000), (Kaston, 1978). A general description of spiders from all over the world has been provided by Preston-Mafham and Preston-Mafham (1986). The distribution of spiders in Rice lands of South Asia has been well recorded and illustrated by Barrion and Litsinger (1996). Information of diversity of spiders of Australia, Southern United States and Mexico, Europe and Canada (Website #1) is available on internet.

Indian literature

The knowledge on diversity and distribution of spiders in India is sparse as compared to other regions of the world listed above. The most comprehensive description yet on Indian spiders is by Tikader (1987). This Handbook does not provide the region in which the spider species listed is found. A brief account of spiders is also provided by Vijayalakshmi and Ahimaz (1993). The first detailed account of Indian spiders was provided by Pocock (1900) which lists 216 spider species under 17 families. Among the other early accounts is that of Gravely (1922). Tikader (1987) has listed 1066 under 43 families. Table 1 lists the number of spider species among major families found in India. Five of them namely, Lycosidae, Salticidae, Gnaphosidae, Thomisidae and Araneidae are the predominant ones. Each of these families constitutes

about ten percent or more of the spider fauna recorded by Tikader (1987). Currently there are very few workers actively involved in surveying and recording Indian spiders (Ganeshkumar and Mohanasundram, 1998). Thus a pressing need exists to explore spider diversity in the country. The following example illustrates the shortcoming. The Canadian Biodiversity Survey has recorded about 1400 species of spiders in Canada (Website # 1). Canada is known for its cold climate and a relatively limited biodiversity. Added to that, it is a vast country and many times larger than India, which renders a survey at the national level, daunting. Under these circumstances 1400 species have been documented. In comparison India has a very rich diversity, smaller area to be surveyed, has a tropical climate with a biodiversity hotspot, has manpower to conduct biodiversity surveys, but the best account so far (Tikader, 1987) lists 1066 spider species.

Table 1. Families of spiders with ten or more species occurring in India (Tikader 1987).

Family	Number of species	Family	Number of Species
Barychelidae	10	Tetragnathidae	22
Oonopidae	10	Oxyopidae	32
Hersilidae	12	Theridiidae	49
Scytodidae	12	Theraphosidae	50
Linyphidae	12	Heteropodidae	65
Ctenide	13	Clubionidae	69
Agelenidae	13	Lycosidae	97
Pisauridae	13	Salticidae	100
Ctenizidae	14	Gnaphosidae	108
Zodaridae	14	Thomisidae	117
Uloboridae	15	Araneidae	142
Dictynidae	16		

Spiders in Western Ghats

For reasons mentioned above, we have set about to survey and record the distribution, diversity and biology of spiders. Western Ghats is one of the regions rich in biodiversity and endemic species and an account of spider fauna in this region is not available. Our expectation of finding a rich diversity of spiders in the Western Ghats was an educated guess. Taxonomy of spiders is an ambiguous area and consolidated information is lacking. Our observations therefore arrive only at the level of family or at best genus level. One of the impediments in preservation of spiders is the fact that unlike insects, spiders cannot be dry-mounted. The cuticle being soft, spiders tend to shrink and disfigure on drying. Such specimens loose their coloration and hence impede taxonomic studies. We therefore, photograph specimens either in the field or

as soon as they are brought to the laboratory. Among other authors, keys for identification of spiders is provided by Tikader (1987), Barrion and Litsinger (1995), Roth (1993). We have in our wet collection a total of 200 species of spiders. Identification of these is in progress. Based on our observations we have collated the eye patterns of spiders (Fig. 1) which can also be used as a key for identification.

The occurrence of major spider families and their relative abundance in the central Western Ghats as revealed by our observations is listed below. Our surveys at present are confined to arboreal spiders and does not include epigeal and litter spiders. The major representation is from the families Oxyopidae, Thomisidae, Araneidae and Salticidae. The Western Ghats regions are characterized by heavy rains averaging 3000 mm between June – August. We have also observed seasonal fluctuations in relative abundance.

Table 2. Relative abundance of major arboreal spider families in the central Western Ghats.

Family	Percentage
Hersilidae	2.9
Linyphidae	4.2
Oxyopidae	5.4
Thomisidae	11.9
Salticidae	26.2
Araneidae	38.0

We took this as baseline data and extended our studies to observe whether the agricultural activities, which are an important factor in influencing the fauna do influence the spider fauna. Western Ghats are fragmented in many places due to agriculture including horticulture. As compared to the diversity of spiders shown above the garden crops arboreal spiders showed lesser diversity. The relative abundance of spiders among garden crops (Poornima, 2001) is as shown in Table 3.

Table 3.

Plant species	Araneidae	Salticidae	Thomisidae	Uloboridae	Linyphidae
Psidium gujava	15	11	1	1	1
Areca catechu	25	1	2		
Thevea indica	8	4	1		
Hevea brasilensis	7	5			
Caesalpenia pulcherima	9	24	3		

Seasonal variation of spiders

The density of spider was high during the pre-monsoon season and gradually decreased during monsoon. On some plants like *Areca* and *Ceasalpinia* they were abundant in the month of December and their number decreased by end of January. There was considerable variation in the members of *Araneidae* during rainy season and winter. In *Areca* plant *Gasteracantha* species are abundant, which suggests that species prefer specfic habitats. Flowering plants such as *Nyctanthus* have high density of spider belonging to Thomisdae.

The foothills of Western Ghats are often converted to monoculture gardens like Cashew. In an study concentrating on diversity of spiders on cashew, we collected 156 specimens and the major families of spiders observed were: Araneidae, Salticidae, Thomisidae, Oxyopidae (Raghavendra, 2001). Except Araneidae the others are non web-building hunters. There was also a seasonal fluctuation in their density with maximum diversity in spring. This corresponds to the seasonal occurrence of pests on the cashew crop (Devasahayam and Sunderaraju, 1987). Comparatively the diversity of spiders is less in the garden crops. A reason for this decline is use of pesticides. Crab-spiders (Thomosidae) are more in the garden crops and they are lesser in pristine forest areas. Members of Hersilidae, Heteropodidae, Clubionidae, Palpimonidae, Lycosidae, Tetragnathidae, are absent in the garden. Thus by comparison it is evident that conversion of pristine forests to agricultural land reduces diversity of spiders.

Recommendations

1. Faunal diversity surveys and conservation efforts are often concerned with charismatic species like higher vertebrates. We need to pay attention to other faunal components also, like spiders because of the significant ecological role the play.

2. In order to formulate conservation measures a baseline data about a particular group is needed. For many of the arthropods such information is lacking and therefore needs to be generated.

3. Deforestation selectively reduces diversity and density of fauna like that of spiders. Additionally, use of pesticides may dramatically influence their diversity. It would be worthwhile designing insecticides such that they are less toxic to spiders.

4. Spiders appear to be promising candidates and can be used in biological control of pests.

Spiders exhibit stunning morphological diversity and coloration. An ant-mimicking spider of the genus *Myrmarachne* belongs to salticidae. The salticid on top right panel shows brilliant coloration. The coloration of spiders comes both from colored hairs or pigments incorporated into the cuticle or placed below it. Orb-weaving Araneidae members have large abdomen and Oxyopidae are characterized by spiny hairs on the body. Oxyopidae (Lynx spiders) and Salticidae (Jumping spiders) members are hunters and do not spin webs.

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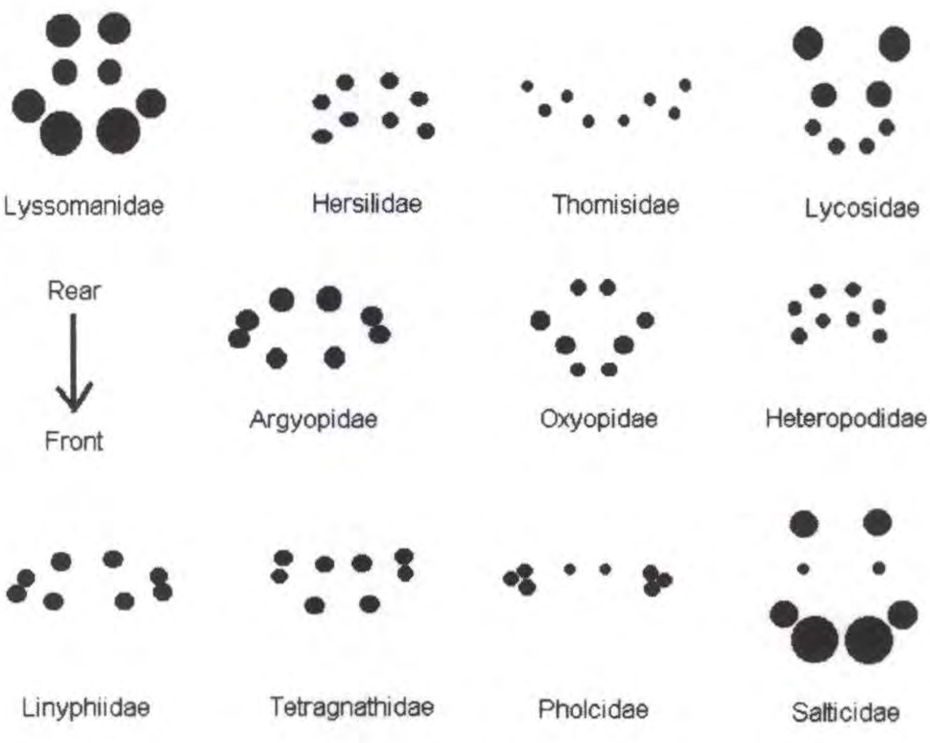

Fig. 1. Variations in eye patterns cahracteristic to spiders belonging to different families

Chapter 8

WHITEFLY SYSTEMATICS (ALEYRODIDAE : HEMIPTERA: INSECTA)

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Introduction

Whiteflies are minute usually inconspicuous plant bugs mostly found infesting the foliage of plants. They are so called because the adults are small, fly-like, often dull white in colour. The powdery wax on their membranous wings give the alternative name 'mealy wing' *("aleuron"* in Greek meaning 'flour'). Adults measuring 1-3 mm in body length also have remarkable superficial resemblance to tiny moths. Indeed, the European cabbage whitefly (*Aleyrodes .proletella)* was initially described as a moth by Linnaeus (1758) and only later recognised as a hemipterous bug by Latrielle (1795).

Recently, these bugs have posed great threats to agriculturists almost throughout the world. Though, a mainly tropical group, injurious species are noticed in the temperate zones of the world and several of them are serious pests in glass house and green house conditions. The Aleyrodids (whiteflies) belong to the order Hemiptera and comprise a single superfamily Aleyrodoidea and family Aleyrodidae within the suborder Homoptera and division Sternorrhyncha. Of the four groups of sternorrhynchous hemiptera, the whitefly is the least speciose group with around 1450 named species compared to 6000 coccoids, 4400 aphidoids and 2500 psyllids (Martin, Mifsud & Rapisarda, 2000).

Whitefly eggs are borne on pedicels. The first instar larvae termed crawlers are mobile and can crawl a short distance to locate suitable feeding sites. Once the first moult has taken place, however, the remaining three larval instars are sessile. The fourth instar is often referred to as a pupa. However, it not a true pupa since feeding occurs in the first part of the stage and transformation in to adult takes place in the last part without any pupal moult (Gill, 1990).

The systematics of this family is primarily based on the structural features of the 'pupa' or the vacated exoskeleton being termed as a 'pupal case', and not on the adults as the former exhibits a multitude of diagnostic characters than the latter. This has the great advantage that since the pupal case are sessile it is possible to collect and identify host plants with the insects. Unfortunately, some polyphagous whitefly species vary in the appearance of their pupal cases depending on the form of the host plant cuticle on which they develop (Mound, 1963).

A comparative study of structure of adults from a wide range of whitefly species is a high priority for future taxonomic research, as this can be expected to be of value both in recognizing species and possibly biotypes, and also in clarifying systematic relationships (Bink & Mound, 1990).

The aleyrodid fauna of Eastern and Western Ghats of India is poorly understood except for Meganathan & David (1994) on the aleyrodid fauna of Silent Valley and description of whiteflies from parts of Western Ghats by David & Selvakumaran (1987), Jesudasan & David (1991), Regu & David (1993), Sundararaj & David (1993) and

David (1994). Considering the lacuna existing in the knowledge of whitefly in the Eastern and Western Ghats, there is large scope for more detailed investigations on this group of insects infesting forest trees in these regions.

Economic Importance of Whitelies

Whiteflies are regarded in India to be primarily the pests of vegetables, crops, citrus, ornamental plants, sugarcane, cotton, and are also found to infest forest trees like teak and fruit trees like guava, papaya, banana etc.,

Both nymphs and adults feed via stylet mouthparts with which they pierce plant tissues and suck phloem sap. These insects often produce a large amount of sugar-rich excreta, whilst extracting sufficient protein-building amino acids from the sap to facilitate body growth. These excreta, termed 'honeydew' may support the growth of sooty mould on affected plants. Large infestations of whiteflies may thus adversely affect their hosts, both by excessive sap loss and through sooty mould interfering with photosynthesis (Martin, Aguiar & Baufeld, 2001).

Whitefly borne viral diseases transmitted by the adults are one of major importance in tropical and subtropical agriculture, with more than 70 diseases and a range of symptoms being reported on cultivated and weed plants (Cohen, 1990; Bedford, Briddon, Brown, Rosell & Markham,1994). Although relatively few whiteflies are normally ant-attended, ants may be attracted to the honeydew of large colonies and their presence may interfere with natural enemies of the whiteflies and of other pests in their vicinity. Secondary damage can be caused by some whitefly species as copious production of woolly 'wax' secretion soil the plant canopies. Some whiteflies may also deform the leaves, which would be detrimental to the marketability of such plants even if the whiteflies themselves have been eradicated (Martin, Mifsud & Rapisarda, 2000).

With the ever increasing worldwide trade in living plant material, whether as vegetables for human consumption or as ornamental plants, several whitefly species have already significantly extended their distribution and it may be expected that this trend will continue despite the best efforts of Port Plant Quarantine officials. This risk is probably underestimated by many, if not most countries. Invasion of *Aleurocanthus* spp., *Aleurodicus dispersus* and *Bemisia tabaci* through quarantine routes into Europe and India should not be overlooked as large populations of whiteflies can migrate in this manner and eventually cause havoc to our flora in the future.

Whiteflies of The World

Jesudasan & David (1991) in their monograph on whiteflies of India have comprehensively reviewed the world literature since seventeenth century till 1991. Bink (1992) observed the setal length variation in whiteflies in relation to leaf surface in Mediterranean evergreen oaks, while, Ko, Hsu & Wu (1992) discussing the taxonomy of eight Taiwanese species of *Rhachisphora* Quaintance & Baker (1917), described

three new species. Liu & Oetting (1993) described and illustrated all stages in the life cycle of aleyrodids like *Bemisia tabaci, Trialeurodes vaporariorum,* and *T. abutilionea.* The aleyrodids of Venezuela (Arnal, Russell, Debrot, Ramos, Cermeli, Marcano & Montagne, 1993), of central and northern America (Martin & Polaszek, 1999), of Australia (Martin, 1999), of Europe and Mediterranean region (Martin 2000; Martin, Mifsud & Rapisarda, 2000), of Hong Kong, Hawaii and Florida (Martin, 2001), of South east Asia (Martin & Camus, 2001) and of Macaronesia and Pacific region (Martin, Aguiar & Baufeld, 2001) are some of the latest additions to our understanding of aleyrodid fauna of the world.

Whiteflies Of India

Though the study on Indian Aleyrodidae began as early as in 1895 by Maskell, who described 5 new species, further additions to the whitefly list were made by Peal (1903), Quaintance Baker (1917) and Dozier (1928). Singh (1931), who described 25 new species, made first detailed study and documentation of North Indian whiteflies. David & Subramaniam (1976) investigated the whiteflies of India with special reference to south Indian species. They reported 60 species under 24 genera, of which 30 were new to science. They also provided detailed keys to the genera and species of Indian Aleyrodidae. David (1972,1976,1977,1978,1981,1987a,b and 1988) described several new species, which include two species of the genus *Odontaleyrodes* Takahashi, three species of *Aleurotuberculatus* Takahashi, one species each of *Setaleyrodes* Takahashi, *Aleuromarginatus* Corbett and *Aleurodicus* Douglas. The species *Aleurodicus philomenae* was recorded for the first time in India from the subfamily Aleurodicinae. However, recently David & Selvakumaran (1990) synonymized this species with *Aleurodicus machili* Takahashi. David (1987a) reviewed the host-correlated variations in whiteflies; proposed the new combination *Aleuromarginatlus bauhiniae* (David) for *Trialeurodes bauhiniae* Corbett and *Aleuromarginatus thirumurthiensis* (David) for *Aleuromarginatus bauhiniae* David (1988); accommodated 35 genera of Indian Aleyrodidae under 12 tribes, of which five, namely Aleuroplatini, Bemisini, Lipaleyrodini, Tetraleurodini and Zaphanerini were proposed as new (1990); highlighted the biodiversity in whiteflies in terms of host-correlated variation, biotypes/ races, host plant preferences and life cycles and impact of pesticides on whitefly population and dynamics (1993 a); the same year published a monograph on the whitefly of Sri Lanka (1993 b); summarised his Post-Doctoral contributions, the highlights of which include the list of known number of species from India as 284 with the total species he described himself or with his students accounting for 63.8% (1994).

David & Jesudasan (1987,1988) described a new genus *Crescentaleyrodes* for *Aleurolobus semilunaris* (Corbett) and added two new species *Aleuroclava orientalis* and *Aleurolobus orientalis* from India and Sri Lanka. David & Jesudasan (1989a) proposed *Dialeurolonga maculata* (Singh) for *Aleurotulus maculata* (Singh) and a new name *Dialeurolonga takahashi* for *D. maculata* Takahashi. The same year (1989b) they redescribed *Aleyrodes shizuokensis* Kuwana.

Jesudasan & David (1990), revising the genera *Aleuroclava* Singh and *Aleurotuberculatus* Takahashi of India, erected four new genera, viz., *Dumbletoniellla, Martiniella, Minutaleyrodes* and *Ryoichiella*. Jesudasan & David (1991) in their monograph on Indian Aleyrodidae reported 166 species under 38 genera, described 61 new species; proposed one new combination, i.e., *Pealius simplex* (Singh) for *Aleurocanthus simplex* Singh; synonymised *Acaudaleyrodes citri* Priesner & Hosny with *Acaudaleyrodes rachipora* (Singh), *Dialeurodes glomerata* Singh and *Pealius indicus* David & Subramaniam with *P. simplex* (Singh), and *Aleuroplatus spinus* (Takahashi) with *Pealius spina* (Singh); and reported the genera *Cohicaleyrodes* Bink and *Moundiella* David for the first time from India. In 1994, Jesudasan & David studied the association of aleyrodids with other species of aleyrodids and with other insects.

David & Selvakumaran (1987) described *Mixaleyrodes indicus* from *Litsea travancorica*. David & Augustine (1988) described *Bemisia graminis* as a new species from *Apluda mutica*. However, this species was later synonymised with *Bemisia tabaci* (Gennadius). David & Regu (1989) provided the description for a new species *Aleurocanthus indicus* from *Borreria hispida*, they in 1991 recorded *Rhachisphora rutherfordi* Quaintance & Baker for the first time in India on *Loranthus elasticus*. David & Sundararaj (1991) described *Pealius cinnamomi* from *Cinnamomum* sp. and *Setaleyrodes litseae* from *Litsea* sp., in 1992, they described *Dialeurodes delhiensis* on *Ficus* sp.; in 1993, they erected the genus *Kanakarajiella* for *Dialeurodes vulgaris* (Singh), proposed four new combinations and provided a key. David & Thenmozhi (1995) made a detailed study on the characteristics of adults and eggs of four species of *Lipaleyrodes* besides describing a new species as *Llpaleyrodes vernoniae* on *Vernonia cinerea*.

David, Jesudasan & Mathew (1988) described a new species *Aleurolobus gmelinae* from *Gmelina arbonea*. David, Sundararaj & Regu (1991) described four new species of *Odontaleyrodes* Takahashi, providing a key to the Indian species. David, Krishnan & Meganathan (1994) described a new species of *Aleurolonga* Mound as *Aleurolonga indica* from *Dichrostachys cinerea*, the genus being a first report from India. David, Krishnan & Thenmozhi (1994) described a new species as *Viennotaleyrodes nilagiriensis* and synonymized *Viennotaleyrodes lafonti* (Cohic) and *Viennotaleyrodes indicus* with *Viennotaleyrodes megapapillae* (Singh).

Sundararaj (1989) studied the Indian Aleyrodidae of the tribe Aleurolobini. Dominik (1989) reported 20 new species of whiteflies. Sundararaj & David (1990) described a new species *Bemisia multituberculata* from *Gmelina* sp.; described two species of *Rhachisphora* Quaintance & Baker as *Rhachisphora indica* and *Rhachisphora ixorae* (1991a); elevated *Dialeuronomada* Quaintance & Baker, a subgenus of *Dialeurodes* Cockerell to generic level and described ten new species, provided a key to the India species (1991 b); erected the genus *Cockerelliella,* described five new species and assigned five species of *Dialeurodes* Cockerell to this new genus, and described a new species *Asialeyrodes indicus* as well, the genus *Asialeyrodes* Corbett being the first record from India (1991c);erected the new genus *Fippataleyrodes*, described two

new species as *Fippataleyrodes indica* from *Ficus racemosa* and *Fippataleyrodes litseae* from *Litsea stocksii* (1992a); they studied the intraspecific diversity in *Dialeurodes kirkaldyi* (Kotinsky) on different host plants (1992 b);described 14 new species of *Aleuroclava* (Singh) with a key to Indian species 1(1993a);recorded for the first time in India two new species of the genus *Martiniella* Jesudasan & David and described them as *Martiniella ayyari* from *Mussaenda* sp. and *Martiniellla lefroyi* from *Etatastemma* sp.(1993b);elevated the subgenus *Gigaleurodes* Quaintance & Baker to generic level and reported the species *Gigaleurodes multipori* to occur for the first time in India (1994).

Regu & David (1990) described *Rhachisphora elongatus* from *Mimusops elengi*, described a new species of *Bemisia* Quaintance & Baker as *Bemisia capitata* from *Rivea hypocrateriformis* (1991a); described two new species on *Ixora brachiata* as *Asialeyrodes meghalayensis* and *Asialeyrodes papillatus* (1991b); described a new species of *Dialeuropora* Quaintance & Baker as *Dialeuropora heptapora* from *Hiptage* sp. (1991c); described two new species of *Aleurodicus* Douglas as *Aleurodicus indicus* from *Polyalthia superosa* and *Aleurodicus holmesii* from *Dimocarpus longan* (1992a); described a new species *Aleurotrachelus saklespurensis* from *Dimocarpus longan* (1992b); described three new species of whiteflies belonging to the tribe Dialeurodini as *Cockerelliella rotunda* from *Capparis* sp., *Dialeurodes* (*Gigaleurodes*) *splendens* from *Homonoia riparia* and *Dialeuronomada saklespurensis* from *Dimocarpus longan* (1992c); described two new species, namely, *Aleurocanthus ayyari* from *Calophyllum inophyllum* and *Tetraleurodes kunnathoorensis* from *Streblus asper* (1993a); described a new species as *Asialeyrodes saklespurensis* from *Olea* sp. (1993b), and, studied 54 species of Indian Aleyrodidae under 6 genera of the tribe Aleurolobini, erected a new genus *Aleuropapillatus*, described 31 new species, studied the host-correlated variation in *Aleurolobus niloticus* and *Aleurolobus orientalis*, suggested two new combinations and provided a detailed key to the tribes of the subfamily Aleyrodinae along with the checklist giving their hosts and distribution (1993c).

Meganathan & David (1994), studying the aleyrodid fauna of the silent valley, a tropical evergreen rain forest in Kerala, erected three new genera, namely *Hindaleyrodes*, *Keraleyrodes* and *Rositaleyrodes*, described 17 new species and reported two genera, viz., *Acanthobemisia* Takahashi and *Parabemisia* Takahashi to occur for the first time in India.

Two new species viz., *Aleurocanthus arecae* infesting *Areca catechu* (David & Manjunatha, 2003), *Aleurocanthus musae* on *Musa* sp. (David & Jesudasan, 2002) have been reported recently from Shimoga (Karnataka) and Andaman & Nicobar Islands, respectively. Further, a new whitefly *Vasdavidius setiferus* (Quaintance & Baker) has been reported from India (Dominik, David & Mohanasundaram, 2001).

Future Taxonomic Work

Sophisticated techniques such as electrophoresis, cytology, cuticular hydro-carbon

analysis and DNA probes, each of which have proven useful in recognizing closely related species of insects in groups such as aphids (Blackman, Brown & Eastop, 1987), simuliid blackfly vectors of human diseases (Post, 1985) and even in aleyrodids on esterase electromorphs in *Bemisia tabaci* (Brown, Coats, Bedford, Markham, Bird & Frohlich, 1995) and molecular mechanisms of biotype determination in *Bemisia tabaci* (Paul De Barro & Driver, 1997). Future taxonomic work on whitefly must be field oriented, involving studies on the living insects both as immatures and as adults in addition to the utilization of morphological and biochemical characteristics (Bink & Mound, 1990).

Management

Of the many species of whiteflies infesting economically important crops, *Bemisia tabaci* on a wide range of host plants, *Aleurocanthus woglumi* on citrus, *Aleurolobus barodensis* on sugarcane and recently *Aleurodicus dispersus* on papaya, guava have caused intensive damage. To combat the ravages by these whiteflies, especially the cotton whitefly, various groups of insecticides have been used including the synthetic pyrethroids. However, the whiteflies, like other notorious insect pests, have developed resistance against them. Insecticide-induced resurgence and secondary outbreak of whiteflies (David, Jesudasan & Augustine, 1986) have resulted in acute crop loss in cotton growing areas of Andhra Pradesh, Tamil Nadu and Karnataka. Management of key whitefly pests incorporating biocontrol agents such as parasitoids, predators, *Bacillus thuringiensis*, entomogenous fungi, NPV, etc., continues to be an ideal approach in crop protection as these agents are efficacious and safe to the environment.

Summary

Whiteflies have received great attention throughout the world owing to their sudden appearance in large numbers on economically important crops. Both the nymphs and adults inflict damage to plants by sucking the plant sap, the adults being a vector of many plant viral diseases and exudation of honey dew by nymphs forming a substratum for the development of sooty mould fungi.

The whiteflies have four nymphal instars and the last nymphal instar often referred to as the 'Pupa' or 'Puparium'. The pupa or the vacated exoskeleton called the 'Pupal case' is considered for the systematics of this group, as that stadium is sessile and exhibits a multitude of diagnostic features while the adult stage is fully mobile.

Of the approximately 1450 species recorded throughout the world, around 290 species have been reported from India and the family Aleyrodidae is considered to be the least speciose among all the four groups of sternorrhynchous hemiptera.

Studies on Indian Aleyrodidae though began as early as 1895 by Maskell (1895) and continued by Buckton (1903), Peal (1903), Quaintance & Baker (1917), Singh (1931), Takahashi (1950), David & Subramaniam (1976), Jesudasan & David (1991), Sundararaj & David (1993), Regu & David (1993), Meganathan & David (1994), have not reached

an appreciable status considering the wide diversity of flora on which the whiteflies inhabit in varied agroclimatic zones.

Of the several whitefly species recorded in India, a few are economically important as they infest cash crops like cotton, brinjal, citrus, sugarcane, etc. Bioecological studies and management of *Bemisia tabaci* have been carried out, though detailed investigations are needed for the other species of whiteflies such as *Aleurolobus barodensis* infesting sugarcane, *Aleurocanthus woglumi* infesting citrus and the spiralling whitefly *Aleurodicus dispersus.*

Whiteflies are still to be explored in the biologically rich areas such as Eastern and Western ghats. There is need for study on the natural enemies and ants associated with the aleyrodids in different parts of India.

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Chapter 9

LAND SNAILS OF WESTERN GHATS

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> *"As every specialist of gastropod morphology will know, we are still far from having natural system of the gastropods, and extensive studies will be necessary to develop one.... With adequate knowledge of the phylogeny, one rule would be suffice; "to place in a systematic group always all and only such forms which are derived from a common ancestor".*
>
> *Adolf Naef, (1911).*

Introduction

Molluscs constitute the second largest invertebrate and most successful group next only to insects (Abbot, 1989, Bouchet, 1991). It has been here for over 500 millions years. The estimate of number of species of molluscs today varies from 80,000species (Boss, 1973) to 135,000 (van Bruggen, 1955). Of these 31,000 – 100,000 are marine, 14,000 – 35,000 terrestrial and about 5,000 freshwater species (Abbott, 1989; Seddon 2000). In spite of great diversity, the land molluscs did not receive much attention till recently. The tropical rain forests are known for their rich land snail diversity and majority of them are found in the leaf litters and in the soil (Emberton, 1996) and their biomass is of great ecological significance

Western Ghats/Sri Lanka is one of the twenty-five hotspots of the world (Myers, et. al., 2000) and is known for its rich flora and fauna with high endemism (Groomridge 1994; Madhyastha, 2000). The Western Ghats (WG) is an impressive, heterogeneous and archaic mountain system dating back to 80MYA. The climatic conditions vary from 5-6 months of wet season in the South to almost 1-2 months in the North. Faunal diversities accordingly vary form high in the Southern parts to low in the Northern drier regions. Human habitation, slash and burn cultivations were common through centuries in WG (Sturrock, 1894) yet; the tropical rains forests of WG were fairly rich till a century ago (Madhyastha, 2000). The high rate of population growth and population pressure, infiltration into forests through hundreds of roads, railways lines and expansion of agriculture has reduced forest cover drastically. Population pressure is single largest cause for extinction of species in WG (Cincotta, et al., 2000).

Seasonal rainfall pattern of Western Ghats necessitates the diapauses for the land snails, results in abundant and high diversity levels (Emberton, 97). They form an important group of soil invertebrates, and serve as the indicators of soil/leaf litter biodiversity and soil calcium level. The little known micro gastropods of soil/litter of WG are soil transformers and are important links in the terrestrial food chain.

It is in this context WG deserves special attention for conservation, inventorying and monitoring of molluscs apart from other groups of organisms both better known and lesser-known ones. The land snails of WG are very diverse and abundant (table 1 and 2), (Naggs, 2000a; Gude, 1921; Sathyamurthi, 1960) but hardly any systematic studies have been made ever since the three volumes of Fauna of British India was published (1914, 1915, and 1925).

The land snails of WG are particularly well suited for biogeography due to their great evolutionary and faunal stabilities (Emberton, 1996) and because many Madagascan

snails have very strong Indo-African connection and high endemics. Unfortunately, for the last one hundred years or so, no attention has been paid for this important group and particularly in WG, although there are some localized studies and reviews (Tonapi, 1971; Mitra and Subba Rao 1979; and Sathymurthi 1960; Naggs, 1997; Seddon, 2000).

Pioneering Studies

The pioneers in the field of Indian Malacology were the British. William Benson (1821) was the first and the most inspiring Malacologist in India (Naggs 1997). His inspiring leadership had resulted in many enthusiastic malacologists who succeeded him. As a result the nineteenth century had seen many outstanding contributions on land snails. Benson himself had published 57 papers on land snails.

Thomas Hutton, a contemporary of Benson published a paper on Indian land snails as early in 1834 in the Journal of Asiatic Society, Bengal. The earliest review of Indian land snails was by Woodward (1856) in which he has listed 350 species. Other luminaries who worked on Indian land snails include, William Theobald (1876-83), W &H Blanford (1867-1914), Godwin-Austen (1882-1921) and others. Theobald with S. Hanley brought out *Conchologia Indica* in 1876. H.H.Godwin-.Austen published a series of 6 books 'Land and freshwater Mollucsa of India between 1882-1920. William Blanford was entrusted with publishing the 'Fauna of British India: Mollusca' but he died before the reversionary study of land snails was completed for volume I. G K Gude (1914) then completed this work. Even today the Fauna of British India series is used as bible for identification of Indian Land snails. The Fauna of British India describes most of the land snails found in WG, but unfortunately, too many descriptions are in Latin and with few illustrations and hence are difficult to use by most of the investigators in India.

In 1916 Zoological Survey of India (ZSI) was established. And all the activities concerning Mollusca which were entrusted to Geological Survey of India, transferred to Indian Museum, was finally brought under ZSI control. All these should have propelled the study of Indian land snails; instead there was a void with few exceptions.

A large series of detailed systematic, structural and anatomical papers on Indian inland molluscs have been contributed to the Records of Memoirs of Indian Museum by many Indian workers like Annandale and Prashad (1919), H S Rao (1925), Sheshaiya (1930) and others contributed to the Records of Memoirs of Indian Museum a large series of detailed systematic, structural and anatomical papers on Indian inland molluscs. The oldest paper on the land snails of the Western Ghats was the Contribution to Indian Malacology No VI., through the descriptions of new land shells from the Nilgiri and Annamallai Hills and other places of Peninsular India by W I Blanford in1866. H S Rao published a paper 'On certain Succineid Molluscs from the Western Ghats'; in Records of Indian Museum in 1925. Other workers mainly contributed paper on freshwater molluscs of WG and not on land snails. Sathyamurthi

in 1960 brought out the "The land and freshwater mollusca in the collection of Madras Government museum" and reported at least 11 new records of land snails from the WG.

Present Status Land Snails

The land snails of WG are by and large in dark, no serious attempts have been made review the existing literature as well (Naggs, 97). Very many species of land snails of WG remain undescribed or under described because of under exploration of the area. Some information is available for the land snails of Pune and neighboring areas (Tonapi and Mulhekar, 1963; Tonapi 1971, and Subbarao and Mitra, 1979).

Zoogeologcially significant genera of molluscs in Indian subcontinent such as *Cyclophorus, Indrella, Diplommantina, and Alycaeus* are endemic. Unique imperial snail, *Hemiplecta basileus* is found in the higher elevation of *WG*, particularly in teak plantations (Subba Rao 1998). *Glessula* is highly diverse (54 sp), both in size (2mm to15mm) and distribution along Western Ghats. There is a need to study the micorgrastropods of soil litter of which no publication is available for Western Ghats. The microgastropods constitute at least one third of the total land snail diversity of the area and form an important component of soil biota. *Acavus,* an endemic genus of Sri Lanka, has been reported from Western Ghats, needs to be looked afresh. In fact, arboreal gastropods of WG are not full appreciated and studied even today.

Needless to say, that the study of land snails of Western Ghats is challenging, interesting and difficult. Most of the land snails are active during monsoon and during summer they hibernate and are difficult to collect. During monsoon, particularly after the first few rainfalls they become active, and the ideal time would be about 10-15 days after the regular monsoon. Micro gastropods (<5mm) are seen clinging to freshly fallen leaves, crawling on the logs and tree trunks. They can be easily collected in the leaf litter of the soil. On the other hand, the Macro gastropods are available on various microhabitats, sometimes actively feeding on the tender leaves or on the mushrooms. Micro gastropods are abundant in places wherever there are too many leeches. Second problem with land snail study is the rain related abundance. Many gastropods are seen on the leaves, logs, rocks, tree trunks, buttress roots, fronds of palms, ferns and other substratum after few hours of heavy rain followed by a few hours of sunshine. Hence either a dry day or a day with heavy rain is not suitable for collection of land snails. One hardly finds a few days in a month during the peak of monsoon, which is ideally suited for the efficient collection of land snails.

Table 1: showing gastropod diversity in India and in Western Ghats

Gastropods	No. in India	No. in WG
Families	26	24
Genera	140	57
Species	1487	258

Experts have warned that the Western Ghats ecosystems are under critical strain from human intrusions in many places, especially in the ecologically complex and sensitive areas of rain forests of Karnataka, Kerala and Tamil Nadu. Dams, plantations and towns have fractioned the forests, hampering the gene flow and destabilizing animal populations. Land species are more subject to local extinctions, which often mean total extinction of localized endemic species and local imbalance. A local imbalance might quickly turn into a disaster due to the patchy distribution of land molluscs. A few species might disappear even before they are being collected and studied. Many terrestrial snails are minute and die silently. Being indicator of leaf litter and soil health, loss of tiny decomposers would mean the signal to disaster to fragile ecosystems of Western Ghats.

Table 2: Showing the number of families and the genera reported for Western Ghats.

Sl. No.	Name of the Family	No. of Genera
1	Veronicellidae	1
2	Pupinidae	1
3	Diplommantinidae	4
4	Cyclophoridae	11
5	Pomatiopsidae	1
6	Achatinidae	1
7	Subulinidae	5
8	Streptaxidae	2
9	Acavidae	1
10	Plectopylididae	1
11	Camaenidae	4
12	Helicidae	1
13	Succineidae	2
14	Ariophantidae	8
15	Helicarionidae	2
16	Pyramidulidae	1
17	Vertiginidae	1
18	Vallonidae	1
19	Pupillidae	1
20	Ceraustidae	3
21	Bulimindae	1
22	Eudodontidae	1
23	Euconulidae	1
24	Charopidae	2
Total	**24 Families**	**57 Genera**

Future Prospects

Terrestrial molluscs are among the most severely threatened animals (Seddon 2001). Nearly 65% of all the extinctions of modern times are from molluscs (IUCN). In USA of the two hundred species classified as endangered, 79 are molluscs! Unfortunately, we do not have even the baseline data on the land snails of WG, let alone considering status of threat to this significant group of invertebrates. Our own field observations show that there are significant reduction in number, and in many cases, the snails is not being seen in their type localities. The greatest threat to land snails is the habitat destruction due to deforestation.

Considering the paucity of information on land snails and severity of threat to them in WG, the need of the hour is to make an inventory and to study the distribution pattern of them. This is no doubt, a stupendous task when one thinks of about 1,600 kms long Western Ghats. The terrains are heterogonous and many places are inaccessible even today. The study is further complicated by the different kinds of regulations governing the protected areas and reserve forests by the forest departments of different states.

The major problem with taxonomy of molluscs is that of identification and classification. The classification appears to be very superficial based on mainly the shell character. There is need to restructure the families and assign the genera based on the phylogeny (Bogan & Hoeh, 2000). An individual or a single organization cannot fulfill this need, as the task is immense and time consuming. This need calls upon all the malacologists of the world to work in tandem and finally chart out a more reliable phylogenic system of classification. This would not be great problem because of latest communication and technology available for biological sciences. However, it may be noted with great concern that the field taxonomists are fast becoming endangered species themselves with a few specialists left. And more so in malacology field, few remaining experts are getting old without successors; India has only a few authorities on which a finger count can be made. Therefore, the utmost need of the day is to coax the younger generation to take active part in the taxonomic field.

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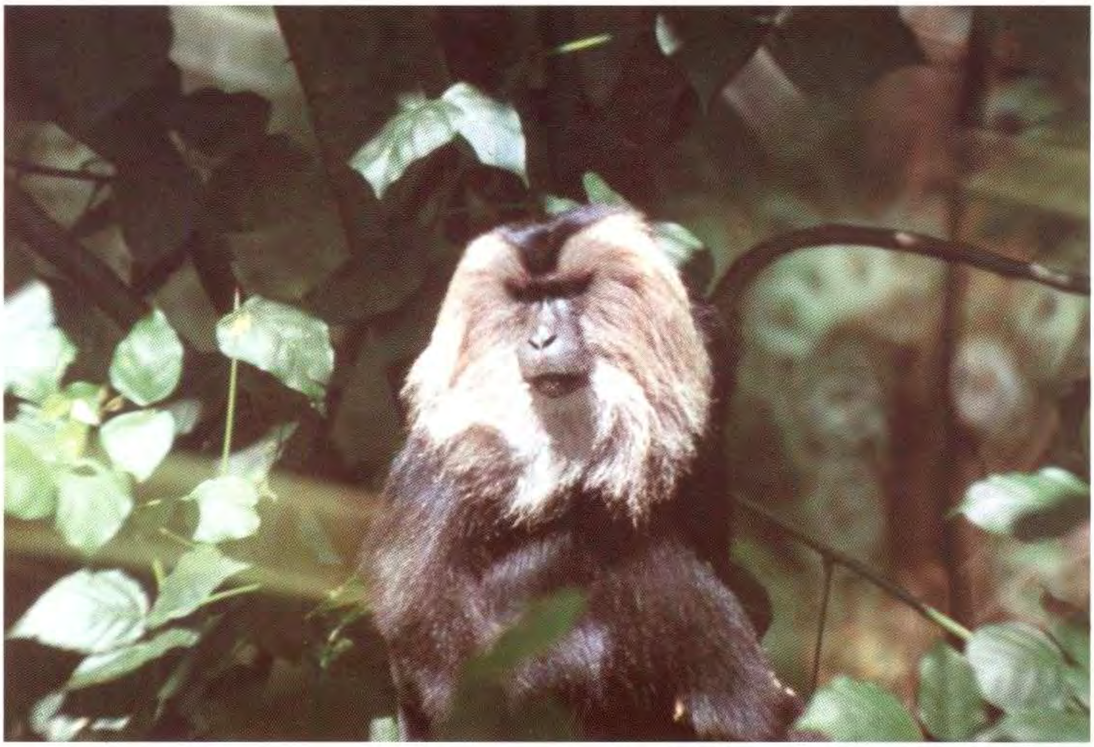
Plate 3



Liontailed Macaque *(Macaca silenus): A.K. Gupta*

Melanobatrachus indicus : S.U. Saravana Kumar

Chapter 10

FISHES OF RAIN FOREST STREAMS/RIVERS OF INDIA A RESEARCH OVERVIEW

M. Arunachalam, J.A. Johnson & A. Sankaranarayanan

Introduction

Fishes are important as they indicate the ecological processes and the producer-consumer interactions. Fish can be used for ecological assessments at all levels of biological organization; assessment procedures are available at the levels of ecosystems, populations, individuals, organs and at the cellular and molecular levels (Harris, 1995). Fish can also be used as indicators over a temporal ranges varying from minutes to decades and spatially from a local scale measured in metres to entire river catchments (Karr, 1991) over thousand kilometers because fish species exhibit diverse morphological, ecological and behavioural adaptations to their natural habitats. Fishes are the intagral components of stream/river systems andn represent a visible measure of stream ecosystem structure and function. Fish assembledge structure and function are also associated with geographic variation and the understanding the pattern is crucial for effective assessment and monitoring of streams/ rivers.

Review of Research

Terrestrial environment has a major impact on drainage basins and stream channels. Patterns of habitat heterogeneity may change due to temporal and spatial changes. Anthropogenic landscape disturbances such as deforestation, row crop agriculture and grazing, shift the structural and functional relationships between the landscape elements and the stability of the physical environment. For small streams, agriculture, deforestation and grazing alter structural relationships among physical components of the streams by either reducing the amount of woody debris entering into the stream and hence the depth, substrates and velocity associated with development (Bisson, *et al.*, 1982; Marzelf, 1978) or by directly removing spatial habitat complexity by channelization. In either case land use activities reduce the (terrestrial to aquatic) allochthonous energy transfers while increasing the instream (autohthonous) energy production (Gregary *et al.*, 1991). This shift from allochthonous to authochthonous energy sources is particularly important to fish in headwater streams as most of the tropical stream fishes rely on allochthonous food sources.

In large rivers, the impact of land-use activities on the structural heterogeneity relies mostly on its floodplains. Construction of flood control structure, removal of large woody debris, closing off of side streams and cleansing of riparian forests disconnects the floodplains from the main channel and decreases the length of lateral boundary between the terrestrial and aquatic environment (Sedell and Forgatt, 1984). As various life stages and species of stream fish require different kinds of physical habitats, spatial heterogeneity and the maintenance of connectivity between habitat patches is critical for the reproduction and survival of fish in lotic ecosystems (Schlosser, 1991). The terrestrial aquatic interface in upstream areas or at the stream margin and flood plain in downstreams allow habitat which are the key factors influencing the population and community dynamics of stream fish.

In the light of the above patterns stream fish ecologists started to focus on establishing relationship between habitat heterogeneity and critical biological processes of population and community dynamics of lotic fishes.

Environmental variability in streams, especially habitat features, has been recognized as determining factors of distribution and abundance pattern for fishes. This aspect has been documented extensively during 1980s throughout the world (Angermeier, 1987; Mahon and Port, 1985; Schlosser, 1982, 1987; Lobb and Orth, 1991; Pringle *et al.,* 1988; Baker and Ross, 1981, Matthews and Hill, 1980; Angermeier and Karr, 1984; Hugueny, 1989; Eadie *et al.,* 1986; Rohm *et al.,* 1987; Matthews and Robinson, 1988; Hughes *et al.,* 1986; Pflieger *et al.,* 1981; Larsen *et al.,* 1986; Whittier *et al.,* 1988; Baecher *et al.,* 1988; Mahon, 1984; Jackson and Harvey, 1989; Coon, 1987; Meffe, 1984; Pusey *et al.,* 1993).

Longitudinal changes in streams between headwater to lower reaches or stream order in relation to fish distribution and assemblages pattern (Matthews, 1986; Osborne and Wiley, 1992; Paller, 1994) have led to the development of lotic paradigms that increase in fish species richness with increasing drainage area. This pattern has been followed across a wide range of latitudes (Lake, 1982; Welcomme, 1985 ; Angermeier and Schlosser, 1989 ; Osbome and Wiley, 1992 ; Beacher *et al.* 1988). Resource use in terms of habitat (Smart and Gee, 1979 ; Hem 1987. Greenberg 1991 ; Barn *et al.* 1988 ; Jowette and Duncan, 1990 ; Fausch and Bramblatt, 1991; Poff and Allan, 1995; Kinzie 1988 ; Pusey *et al.,* 1993), food (Wynes and Wissing, 1982 ; Poff and Allan, 1993 and 1995; Miller, 1983), habitat segregation for depth (Fisher and Pearson, 1987), current (Matthews *et al.* 1982; Gido *et al.,* 2000) and substrate particle size (Mathesan and Brooks, 1983) have been studied in details. Increased siltation in streams and its impact on fish communities have been studied in Central United States (Judy *et al.* 1984; Derkman and Rabeni, 1987). Fish assemblages have been used in detecting anthropogenic impacts (Loeb, 1994 ; Davis and Simon, 1995) and the use of fish communities in surface water assessment was proposed by Karr (1981) in what he termed as Index of Biotic Integrity (IBI). This has been widely used in mid western streams of United States (Karr *et al.* 1986 ; Miller *et al.* 1988 ; Fausch *et al.* 1990 ; Karr, 1991; Hall *et al.,* 1996). Legislative mandate has been specified to protect biological integrity in U.S. Clean Water Act and Canada's National Park Act (Angermeier and Karr, 1994), though there is no mandate in United States to protect biological diversity. But such protection has already been endorsed by many nations as it forms a central goal of 1992 Earth summit.

Tropical diversity of African freshwater species has been dealt in detail (Levaque, 1997) on the diversity and variability, species diversity and evolution, growth and feeding behaviour, reproductive strategies and life history studies, response to environmental constraints, dynamics of fish assemblages and conservation of fish diversity. Studies on tropical Asian rivers are scanty and the only data that are fairly good (and that is only true for some rivers) are fisheries statistics; however they are at

best only a crude estimate of the totality of conditions in a large water body (Hynes, 1989). Extensive studies on freshwater fishes in India are available, but most of them are either concerned with taxonomy (Datta Munshi and Srivastava, 1988 ; Talwar and Jhingran 1991, Menon 1999. Jeyaram, 1999) or with capture fisheries or aquaculture. Much of the published information has been summarized by Jhingran (1992) with extensive bibliography. Studies on fish assemblage structure and their food and habitat requirements in Indian streams are lacking though few initiatives started in the 1980's in Western Ghat streams (Arunachalam *et al.* 1988, 1997 a,b and c; Arunachalam, 2000). Himalayan streams (Edds, 1993) and Sri Lankan streams and reservoirs (Moyle and Senanayake, 1984 ; Wickramanayake and Moyle, 1989 ; Wickramanayake, 1990 ; Piet, 1998; Piet et al. 1999).

In order to manage populations of lakes and streams, geographic framework has been settled for biological criteria (Hughes *et al.* 1994) and this has been widely used for fish assemblage data (Pflieger *et al.* 1981). This eco-region concept has been evolved for evaluating the fish assemblages in catchments, drainage basins and physiographic regions to form icthyogeographic regions. This has been developed widely in United States recently for fish assemblages (Mc Cormick *et al.* 2000; Larsen *et al.* 1986 ; Oswood *et al.*, 2000 VanSickle and Hughes 2000; Schrank *et al.* 2001).

Currently, extensive fish list with few details on abundance but with no habitat feature are available for streams and rivers in Western Ghats (Rao, 1977; Jayaram, 1981; Indra and Remadevi, 1981; Rema Devi and Indra, 1981; Rema Devi and Indra, 1984; Menon, 1984; Rema Devi and Indra, 1986; Ramakrishniah, 1986; Manimekalan, 1998; Kadar, 1989; Kurup and Kuriakose, 1991; Jayaram, 199la and b; Rema Devi and Menon, 1992; Kurup, 1992; Menon and Rema Devi, 1993; Pethiyagoda and Kottelat, 1994; Kurup, 1994; Rema Devi and Menon, 1994; Rema Devi and Menon, 1995; Menon and Rema Devi, 1995; Shaji and Easa, 1995a, b and c; Shaji *et al.*, 1995; Menon and Jacob, 1996; Jeyaram, 1997; Arun *et al.*, 1996; Arun, 1997; Vairavel *et al.*, 1998; Gopi and Radhakrishnan, 1998; Shaji *et al.* 1998; Anmachalam and Sankaranarayanan, 1999; Biju *et al.*, 1999; Raju Thomas *et al.*, 1999; Ajithkumar *et al.* 1999; Jeyaraj *et al.*, 1999; Zacharias and Minimol, 1999; Jayaram and Dhas, 2000; Chhapgar and Manakadam, 2000; Shaji and Easa, 2001; Gopi, 2001) and Eastern Himalayas (Dey, 1975; Dutta and Sen, 1977; Choudary and Sen, 1977; Sen and Choudary, 1977; Sen, 1997; Yazdani, 1977; Yazdani and Rao, 1978; Chadhury, 1978; Ghosh, 1979; Ghosh and Lipton, 1982; Khuda Buksh, 1980; Khuda Buksh and Barat, 1987; Chadhury, 1981; Dutta and Barman, 1984; Viswanath and Sarojnalini 1988; Dutta and Barman, 1985; Sen, 1985; Edds, 1986; Viswanath *et al.*, 1987; Chanda, 1989; Sinha, 1991; Viswanath, 1993; Agarwala, 1994; Yadava and Chandra, 1994; Sen, 1995; Sen and Biswas, 1994; Sen, 1995; Paalab and Chowdhary, 1997; Bhattachariya *et al.*, 1998; Selim and Viswanath, 1998; Viswanath *et al.*, 1998a and b; Sen, 1998a and b; Viswanath and Kosygin 1999 and 2000; Bhowmik and Ayyappan, 2000; Arunkumar and Thombi Singh, 2000; Singht, 2000). Also unpublished reports are available on fish list (Menon, 1992), fish habitat features (Haniffa and

Arunachalam.1999, Arunachalam, 1999, 2000) and food and habitat requirements in the form of Ph.D., thesis (Sankaranarayanan, 1999 ; Antony Johnson, 1999 ; Manimekalan, 2000; Soranam, 2000). Ecology of mahseer (Shrestha, 1997) especially on the habitats, migration, life history, rehabilitation, conservation management and ranching has been studied in detail in the rivers of Nepal. Currently the National Bureau of Fish Genetic Resources, Lucknow has initiated a major research programme on the habitat inventory and germplasm conservation in Western Ghats and Eastern Himalayas with 13 co-operating centres of which the senior author (M.A.) is a major collaborator for Western Ghats.

Conservation Status

Freshwater fishes are the most diverse group of India's vertebrates with a minimum of 600 species (Talwar and Jhingran, 1991). Conservation Assessment and Management Plan (CAMP) workshop (Molur and Walker, 1998) assessed the conservation status of 327 species and nearly 100 more species have not been assessed to date. Since then 10 numbers are recently discovered from Western Ghat and Eastern Himalayas streams/rivers. Based on the recent conservation assessment, 88 species in Western Ghat streams and 82 species in Eastern Himalayas are in threatened category. Of the threatened species nearly 25-30% are highly endemic to their geographic realms. Habitat alterations and degradation, hydrological alterations, introduction of alien/ exotics into reservoirs and over exploitation are the major threats to the rain forest streams of India.

Conservation Approaches

Conservation of all ecological elements at gene, species and ecosystem levels are necessary and current conservation policy is not adequate for protecting ecological elements in a large spatial scale like landscapes. Conservation of fish assemblages are necessary and need a framework for classifying fish assemblages because most aquatic assemblages are probably organized by complex combinations through stochastic and deterministic processes.

In order to prioritize the assemblage level conservation, utilitarian and non-utilitarian goods can be developed. Utilitarian values may come from economic goods and non-utilitarian from less tangible benefits but it warrants conservation because it may consist of rare or endemic species. While selecting assemblages many species-poor assemblages may be valuable because of their unusual organization or assemblages of several regionally rare or endemic species may be more valuable than assemblages of many common forms. Habitat restoration and management goal must be directed at the conservation of assemblages. Even when habitat restoration is contemplated, stock transfer could be an important interim measure. Fish conservation attitude has been changed internationally' and several initiatives have come (Williams and Miller, 1990 ; Maitland and Lyie, 1996) with captive breeding and rearing of rare fish. Conservation status of India's freshwater fishes, especially in

rainforest streams in Western Ghats and Eastern Himalayas is poor. Despite the discovery of several new species to date, the rate of increase of pressure on this fauna is high that extinction may be expected even before discovery.

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Plate 4

Polypedates pleurostictus (in different developmental stages) : S.U. Saravana Kumar

Hemidactylus anamallensis : *S.U. Saravana Kumar*

Chapter 11

NESTING ECOLOGY OF BAYA BIRDS IN THE WESTERN GHAT REGIONS OF KARNATAKA

B.B. Hosetti

- Introduction
- Systematics
- Common names
- Keys for identification
- Study Area
- Methods
- Objectives
- Results and Discussion
- Summary
- Future Scope and significance
- Reference

Introduction

Birds can live in different habitat conditions and these have been blessed with the plumage and flying capacity. The specific aerial adaptations made these birds as the most successful species of the earth. Perhaps, due this reason, the birds are comparatively less affected when compared to other species of wildlife even under the continuous f habitat loss.

In the evolution tree of the animal kingdom, birds stand next to insects as the important animals adopted to live in all types of habitat. These homoeothermic animals are found spread in different parts of the world in different habitat conditions. More than 8650 genera of birds have been identified and studied globally. In India, about 1200 species of birds have been reported from the various parts including about 300 species of migratory birds visiting every year during winter. Salim Ali (1996) classified Indian avifauna into 71 families.

Conservation and management of birds encompasses the aspects like how do men threaten the survival of birds? How do birds harm men and what are the possible measures to solve these problems? Though, India has not lost any bird species, but according to IUCN red data book 6 birds are endangered, 6 are vulnerable, 5 are intermediate, 4 rare and one is prone to extinct (Hosetti and Venkateswaralu, 2001).

According to Ali (1996) the common baya or Indian baya *Ploceus philippinus L.* is widely distributed all over India. However, its ecology has been studied only in Gujarat, Rajasthan and Andhra Pradesh. Ali (1996) reports that *Ploceus bengalesis* is restricted to northern states. In contrast, it is also widely distributed in the south. There are no reports on the presence of *P. manyar* and *P. megharhynchus* in the south. The present paper deals with some general aspects on the ecology of baya birds with special reference to nesting by *P. Philippinus* in the Karnataka state.

This paper deals with the survey of various habitats for nesting colonies of baya, identification of different species baya birds, orientation of nests, nesting behaviour, host plant selection and foraging activity.

Systematics

Out of more than 95 species of weaver birds known to occur in the world, only 4 species are reported from India.

They are classified as follows.

Class	:	Aves
Sub class	:	Neornithes
Order	:	Passeriformes
Family	:	Ploceidae

Sub family	:	Ploceinae
Genus	:	Ploceus
Species	:	*philippinus, bengalensis, manyar and megharhunchus.*

Common names

Name of the Species		Common name
1.	Ploceus philippinus	Common Indian baya
2.	Ploceus bengalensis	Black throated baya
3.	Ploceus manyar	Streaked baya
4.	Ploceus megharhynchus	Finns baya

Keys for identification

The key characteristics described in the book of Indian birds are as follows.

P. Philippinus L.

Male

During breeding season the crown is yellow, rest of the upper parts are dark brown streaked with yellow on the back. Breast yellow, throat and ear dark brown and rest of the under part is cream buff.

Females

Crown and back buff streaked with dark brown, neck yellowish buff, throat is whitish yellow, Breast buff with brown streaks.

During non-breeding season both male and female look more or less alike.

Ploceus bengalensis L.

Male

During breeding season it has dull red crown or golden yellow crown, white throat and black strip separating it from the fulvous white underparts.

Female

Similar to other baya.

Ploceus manyar L.

Male

During breeding season it differs from other baya in having black streak on fulvous breast in both sexes. During non-breeding season both sexes look alike.

Ploceus megharhynchus

Male

This bird is not noticed in the Western Ghats of Karnataka. During breeding season, its head and breast are bright yellow and dark brown streaked on the above.

Female

Head and nape pale brown or yellowish brown with dark streaks.

During non-breeding season sexes are alike.

Study Area

The study area is located in the vicinity of foothills of Western Ghats, receiving an average rainfall of 850 mm. The area is divided into three imaginary zones.

Zone I	:	Northern side
Zone II	:	Northeast
Zone III	:	Southwest

Each zone is spread in approximately 30 hectares land. The topography of the area include 13^0 42' 00" N longitude and 75^0 38' 20" E latitude. Usually the monsoon period commences in the month of June and closes by September.

Among the three species recorded in the study area, *P. philippinus* was most common bird and was found in a variety of habitats and tree species. *P. bengalensis* was found nesting in grasses, reed beds and sugar cane fields and remained away from human settlements. A single colony of *P. manyar* was also found in a most protective habitat in the mid of Navile tank wetland in the Shimoga city.

Methods

In the present study only nesting colonies of *P. philippinus* were enumerated, although the colonies of other species *P. bengalensis and P. manyar* were also encountered. The data collected on *P. philippinus* is used for discussion in this paper. The colonies were located by following their songs and also at times with the help of local people.

A total of 969 colonies were visited in the year 1999-2000. As each male constructs 3-4 nests and each female pairs 3-4 times in a season, the estimate on total number of birds was arrived at around 300-350.

Objectives

The study was undertaken with the following objectives

a. To determine the orientation of nests

b. To know the nesting habitats of the bird

c. To identify the host plants and their diversity

d. To document the breeding activity of the bird

e. To study the feeding activity of the bird

Results and Discussion

Orientation of nests

The study on orientation of nests by *P. philippinus* revealed that the first year male or the yearlings without breeding dress and the sexually matured adult males constructed their nests in all possible orientations, ranging mainly from lateral, central, peripheral sides of the host plants and in all other possible combinations. The types of orientations studied in three zones are showed in Table 1.

In zone I lateral colonies were maximum (81.8%). Such colonies can face different directions in lateral positions. Among these again the colonies facing exactly eastern direction were maximum in number. In zone II again lateral oriented colonies were maximum (80.7%) and of which the eastern side facing colonies were maximum. A similar trend was also noticed in the zone III. A definite orientation pattern was observed in these birds with respect to stem of the host plants. It is generally the entrance tube, which was directed towards outside while the egg chamber was positioned towards the stem. Due to this particular orientation the entrance tube always remained oriented towards outside. The flying routes of the birds are so managed that the host stem or other vegetation do not pose any hindrance. Orientation of these nests was different in vegetated and non vegetated areas, dug wells and irrigation channels, wherein they oriented in relation to their nearest surfaces. *P. philippinus* hangs its nests according to the direction of the prevailing wind.

Selection of twigs

The selection of twigs is also one of the important factors for nest weaving. Twigs should be generally thin, pliable and pendent to horizontal branches (leaves in case of palms and grasses). Twig having thickness more than a thumb are usually avoided, possibly they cannot be accommodated in the grip of claws during knitting of fibers in the nest initiation. Strongly upwarding branches are preferred. Twigs which are sufficiently tough to support the weight of the nest are chosen.

The onset of rainy season in the area is mainly known to influence the nesting activities of the baya birds. The rainy season in Karnataka operates for four months usually from June to September. Any variation in southwest monsoon is found to influence directly on the nesting behaviour and orientation pattern of the nests.

The comparative study of the three field zones in our study area revealed that maximum nest were hanged in the eastwardly direction. The reason for construction of nest in the east may be to avoid or seek protection from Southwest monsoon. But this pattern is not applicable in the case of the situations like open wells, steep wells,

vegetation growing on vertical slopes and sloppy areas. This particular behaviour indicates the intellectual experience gained by the baya to seek protection from natural hazards (Finn, 1990).

Nesting Patterns

A typical normal nest of *P. philippinus* is a bottle shaped nest called as normal nest and can be divided into three parts viz., a stalk, middle body and the entrance tube. The entrance tube is slightly shifted towards the egg chamber to form a bulging chamber.

Abnormal Nests

Besides normal nests, various other types of abnormal nests were constructed by the sexually matured males and yearlings. Many variations can be seen in the nests of baya rendering those abnormal. The category of abnormality is in the structure of the nest or any part of it. Abnormal structure may appear due to deposition of parts formations of additional parts elaboration of parts and abolition of normal parts (Sharma, 1995). The second category of abnormality is regarding the position of nests or any part of it. The abnormality is classified in Table 2.

In our investigation in the Karnataka a total of 969 nests were visited from the three zones I, II and III (Table 3). It is clear from the data that bi-storeyed nesting was common and it was followed by multistalked nests. Why and how and under what situations such nests are constructed by the baya is an interesting and complicating question to be answered.

Tough bi-storeyed nests were common, five storeyed nests were also encountered in the study area. Multistoreyed nests are noticed in those areas where comparatively long monsoon periods prevailed. In Karnataka monsoon period is too short to support the fabrication of 6-10 storeyed nests. Multi stalked nests were also common in this area. Presence of two or more stalks provide extra attachment and strength to the nest which make a hanging nest prone to simple harmonic motions on windy days. To minimize the windy movements of the nests more than one support are used for stalking the nest. Additionally, the length of the stalk is also kept short, which it is mainly based on the habitat conditions. If the tip is harder then more than one stalks are weaved in order to have more security. Stalkless nests are also seen in the area and such nests are equally liked by the females.

The other type of abnormal nests are Bell Jar shaped, buttressed, blind or closed, chained, meshed, branched, fused and stomach shaped nests. In addition to this some normal nests possessed double openings in order to facilitate the quick visits by the mother during feding stage.

The study on nesting pattern in the Western Ghats revealed that 11.9% were abnormal, out of this 14.03% were multistalked and 40.35% bistoreyed respectively (Table 3).

Host Plants

It was observed that in our study area the common baya constructed its nests on 31 species of plants belonging to 18 families. The cocks constructed nests on various types of trees. Among all these host trees, the most preferred trees were of *Cocos nucifera, Acacia planiformes* and *Pheonix sylvestris.*

A comparative study on three zones revealed that Zone I harbored highest number of normal nests (57%) followed by Zone III (55.3%) and Zone II (53.6%). The reason behind this type of variations may be due to presence of rich and varied habitat types. Due to rich habitat resources and protection, the Zone I harbored maximum number of normal nests (Table 4).

Statistical analysis was applied by using Raunkiers frequency test. It is appraránt that low frequency values indicate high number of normal nests with respect to individual species of plants and higher the frequency revealed low the number of nests. According to Raunkiers frequency test the host plants like *Cocos nucifera, Acacia planiformes* and *Pheonix sylvestris* show lowest frequency number indicating maximum normal nests (Table 5).

Summary

The population of common baya was maximum in Zone II due to rich and diverse type habitat and food resources.

More that 50% of the nests were directed towards the eastern side to avoid Southwest monsoon. In contrast, the nest located on the banks of irrigation channels, open wells and sloppy areas showed different orientations.

Among abnormal nests, bistoreyed abnormality was maximum followed by multi-stalked nesting.

A total of 32 different plants species were selected for nesting. Among those, coconut, acacia and phoenix tree species were the ones most preferred.

P. philippinus is not specific in hanging its nests, unlike other species of baya.

Population density of *P. philippinus* was maximum in the study area and it was followed by *P. bengalensis.* Only a single colony of *14 birds P. manyar* species was also recorded.

Future Scope and significance

Among the three species of baya birds, *P. manyar* may considered as endangered species in Karnataka. However, there is need to undertake a detailed survey in other parts of the country. There is also a need to study the pest status of these baya birds in relation to different crops in different areas of our country.

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Table 1. Orientation of nest colonies by Ploceus plrillpplnus

	E	NE	W	CNE	NEW	N	NW	SW	S	SE	NES	SN*	CN	No.of colonies showing central orientation	No.of colonies showing peripheral orientation	Total
	No. of colonies showing different types of lateral orientation with orientation diagrams															
Zone I Total No.	40	13	7	6	4	6	5	-	5	4	2	3	4	12	10	121
Zone II Total No.	67	20	04	17	12	14	06	01	08	09	09	11	02	07	36	223
Zone III Total No.	39	16	04	10	08	09	08		08	06	05	04	04	04	05	130

E = East, W = West, N = North, S = South, C = Central colony, P = Peripheral colony, → = Direction of SW monsoon, O = Tree canopy ■ = Nested part of canopy in respect of South West monsoon, % of lateral colony 93, peripheral colony 3.8, % of central colony 3.0, * Bilateral Colony

Table 2. Classifiction of abnoraml nests

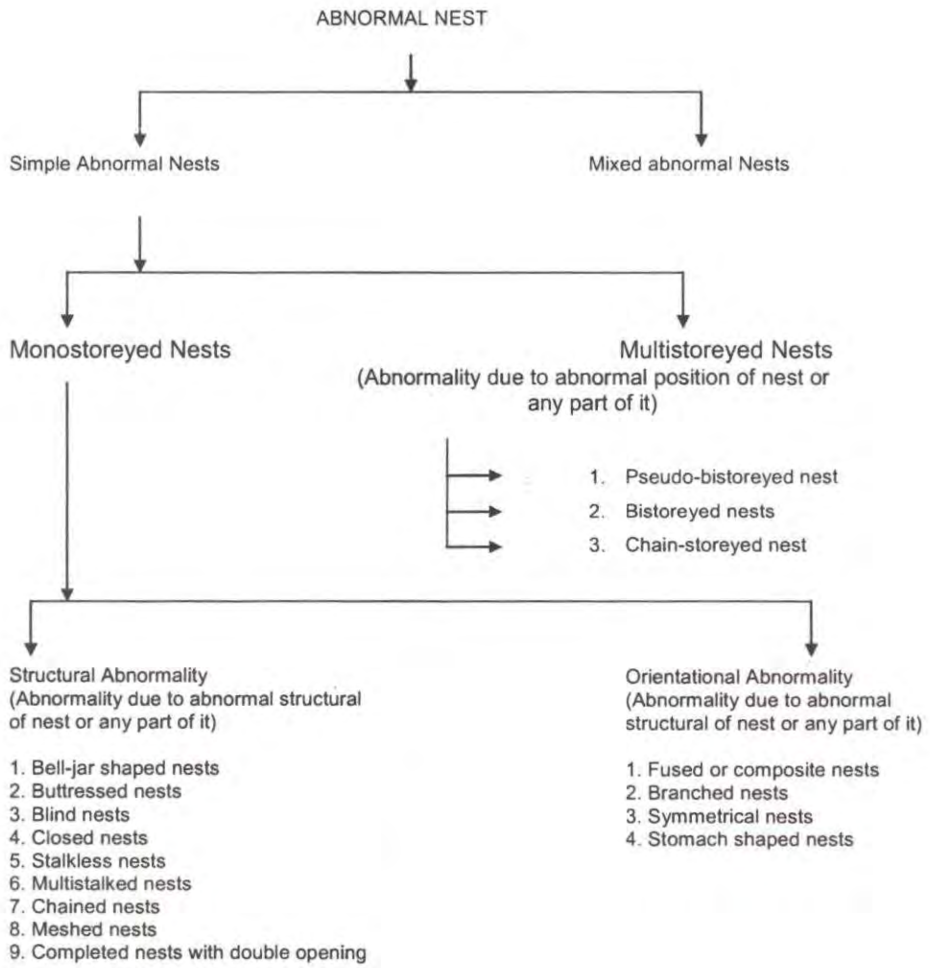

Table 3. Abnormal nests of ploceus philippilus in the Western Ghat area of B.R. Project

Zones	Year	Total no. of nests obse-rved	Simple abnormal nests																Mixed abnor-mal nests	Total number of abnor-mal nests
			Monostoreyed nests													Pseudo-storeyed nests	Bisto-reyed Nests	Chains-toreyed nests		
			Structural Abnormality								Orientational Abnormality									
			Bell Jar Shaped	Buttressed	Blind	Closed	Stalkless	Multistalked	Chained	Meshed	Fused	Branched	Symmetrical	Stomach shaped	Completed nests with Double Opening					
Zone I	1999-2000	374	2	5	-	-	4	6	4	2	1	-	-	1	-	2	18	2	-	47
Zone II	1999-2000	291	-	1	1	-	2	7	1	2	-	-	-	-	-	1	11	-	-	26
ZoneIII	1999-2000	294	1	2	1	1	7	3	4	-	-	-	-	2	1	1	17	2	-	41
Total		969	3	8	2	1	13	16	9	4	1	0	0	3	1	4	46	4	0	114

Zone I = B.R.Project; Zone II = Bhadravathi; Zone III = Shimoga of Shimoga District; Karnataka State

Table 4. List of plants and bottle nests recorded on host Plants

Zone	Total No. of Plants	Total Nests		Percentage of Normal Nests
		Normal (a)	Abnormal (b)	
Zone I	39	374	207	55.3%
Zone II	41	291	196	93.6%
Zone III	49	294	168	57.1%

Table 5. Frequency of complete nests according to Raunkiaers frequency class

Zone	Name of the plant sp.	Frequency Class	Density of Complete Nests
Zone I	Cocos nucifera	A	8.6
	Acacia planiformes	A	17.0
	Pheonix sylvestris	A	42.0
Zone II	Cocos nucifora	A	8.6
	Acacia planiformes	A	12.5
Zone III	Coscos nucifera	A	9.4
	Acacia sp.	A	10.0

Chapter 12

STATUS AND CONSERVATION OF BIRD DIVERSITY IN WESTERN GHATS OF KARNATAKA, SOUTH INDIA

A.K.Chakravarthy

Introduction

The Malnad (which in the local, Kannada or Canarese language means the land of hills covered with forests), is the Western Ghats area of Karnataka in Southern India embracing 25 taluks of eight districts. Of the Biodiversity components, birds are proven bioindicators of environmental quality, change and are ecologically and economically important. Fairly comprehensive studies on Western Ghats (W.G.) avifauna have been published (Betts, 1951; 1952; Taylor, 987; Ali and Ripley, 1974; Ranjit Daniels et al., 1990, 1992; Pramod et al., 1997; Chakravarthy and Tejaswi, 1992; Chakravarthy, 1997; Shankar Raman and Joshi, 2001; Vijayan and Priya Davidar, 2001). Most recent publications on Western Ghats Biodiversity are to be found in Current Science (Volume 73, 1997), in Tropical Ecosystems : Structure, Diversity and Human Welfare, (Editors : K.N.Ganeshaiah and others 2001) and in Trends in Wildlife Biodiversity Conservation and Management (Editors : Hosetti, B.B. and Venkateshwarlu, M.). Yet, at the ground level research based conservation or management measures or interventions are wanting (Utkarsh et al. 2001; Achar et al. 2000). Also the impact of people and their actions in saving and sustaining species diversity are poorly assessed, monitored and integrated (Chakravarthy, 1997). In fact, the interest, land use and importance that the local people attach to an area should form the basis for developing conservation/developmental programmes in that area. This is crucially important because W.G. is world's one of the 25 mega diversity hot spots and home for about 350 endemic plant (Rajendran, 2001) and 324 vertebrates species (Daniels, 2001). Therefore, this paper examines the Research, Conservation and Management issues of bird diversity in the context of their implementation in the field in Malnad, a part of the Western Ghats of Karnataka (WGK).

Western Ghats run parallel to the West Coast covering 21,756 km^2. Moist tropical forests, dry tropical forests, montane sub-tropical forests and montane temperate forests are the four major forest types recognized (Anonymous, 1999). However, in this paper much of the discussion will be on four districts of Malnad viz., Hassan, Chikmagalur, Coorg and Shimoga where field observations on birds are being carried out from 1986 (See Map). Nevertheless, inferences from other parts of Western Ghats have also been drawn.

Malnad receives an annual 261 mm rainfall, of which nearly 83% is received between June and September. The minimum temperature being 6.5^0 C (January) and the maximum is 35.5^0 C (March-May). Malnad is located between 13^0 10' and 13^0 94' North and South, longitudes 75^0 30' and 76^0 85' East and West with elevation of 900 m in major areas and with lateritic soil. In its expanse, Malnad is replete with natural scenery and support a rich variety of geographical features - rolling mountains, deep valleys, bluish-green swamps, streams, tanks, riverbeds, plateaus and forests. Birds provide beauty, colour and endearing sounds and lasting aesthetics.

Comparison and distribution of birds in Malnad with other parts of W.G. can be

understood and appreciated given long term habitat/landscape changes. Exploitation of forests during pre-colonial era was mostly for non-commercial purposes. During the British rule, State Forest Department became the custodian of the forests and controlled large areas of forest. However, substantial forest areas and natural vegetation remained in private control or under Revenue Department. A study by the French Institute of Pondichery and Karnataka Forest Department shows that Karnataka's part of W.G. has 55% of the forest under Reserved Forests (RF) category and 45% outside it, mostly as Revenue Forests (Ramesh and Swaminath, 1999). The study also indicates that 12% of forest cover has been lost in the past two decades. These changes are related to increases in human and livestock populations and consequent pressure on forest land for non forest purposes. Until recently, forest management policies were largely a legacy of the colonical era with it's bias on industrial/commercial uses. Locals had free access to reserved forests and forests were converted to crop lands. About 25% of virgin forests in Malnad is being converted to coffee/cardamom or areca plantations. Coffee pulper or areca processing wastes are being discharged to river streams. The existing forest management policies are incapable of limiting the onslaught on forests.

Currently India being a signatory to International Convention on Biological Diversity, Indian forest policy has given important to Joint Forest Management (JFM) and formation of Village Forest Committees (VFC). The Joint Forest Planning and Management Scheme was implemented in 1993-94 in Malnad for instance in Bhadra wild life sanctuary, Muthodi, Chikmagalur and VFC with 15 membrs was formed in 1994-95. The primary purpose of JFM and VFC was to encourage the villagers to participate in the protection of forests particularly against fire and poaching.

Malnad contributes 12.5% to the Karnataka's Agricultural productivity (Anonymous, 1988). So the productivity of the land and life of the people of Malnad depend much on the way the natural resources are utilised and managed. The sustenance and perpetuation of birds, therefore, is of pivotal importance. Krishna, Bhima, Cauvery, Hemavathi, Bhadra, Tunga, Veda and Yagachi rivers originate from the Malnad. These rivers leave vast expanses of river beds along course of flow which are thronged by the wader birds in large flocks in the winter. The river courses also hold dense vegetation. Relationships between vegetation and birds is crucial to understand biodiversity conservation and management. But, this has remained unattended. Yoganarsimhan et al. (1983), Saldanha and Nicolson (1976), Keshavamurthy and Yoganarasimhan (1990), Rao (1990), Pascal (1988) and Nair and Gadgil (1980) dwelt on different aspects of vegetation in Malnad.

Malnad bears Bauxite, Iron and Manganese in substantial quantities and there has been a great deal of open cast mining for these ores in the area. Each mining centre like Kudremukh is responsible for the loss of natural regeneration extending 8 to 10 km every year. Vegetation in mining areas is represented by broken scrub patches. Such habitats hold few bird species. Kemmungundi and Kudremukh are good

examples for such sites. There is considerable scope for biologists to restore vegetation and wild life in these areas. Uttangi (1993) documented the impact of hydroelectric project on birds in Mahadayi valley, W.G.

Birds of Malnad

Cardew (1895) was the first to document birds of WGK. Davidson (1898) prepared a comprehensive list of birds of North Karnataka, a district adjoining Chikmagalur in the north. He recorded 259 species. Ranjit Daniels added 150 more bird species from the same area after about a century. Betts (1930,1932,1934 and 1938) in a series of articles recorded several aspects of bird life in the Coorg. He recorded 190 species. Betham (1902), Phythian - Adams (1934) and (1939), Brooke - Worth (1953) and Ghorpade (1977) conducted bird surveys. Chakravarthy and Tejaswi (1992) recorded 294 species and Chakravarthy (1997) recorded 313. Davidar (1980) recorded 107 species in the Kudremukh - Aroli - Ganga mula tract in Chikmagalur. Salim Ali (1942-43) with notes by Whistler carried out a survey of the birds of old Mysore and Coorg and did field work from 12 January to 13 February 1940 in Coorg, Sakleshpur (Hassan), Kemmangundi and Jagar valley (Chikmagalur) and in Setihalli, Agumbe and Jog (Shimog). There is no avifaunal work published of Hassan and Shimoga, though C.J.W. Taylor wrote, "A tentative list of the Birds of Manzeerabad (near Sakleshpur, Hassan), Mysore in 1887". Only recently did Gururaja and Co-workers (1993) documented bird-life of urban Shimoga.

Most of the resident, endemic and native forest bird species are not found north of Goa. Endemic bird species are primarily birds of rain forests and the higher elevation shola grassland complexes (Daniels, 1997). Locally, when equal areas are compared, there are more species of birds per unit area in the central parts of the W.G. This is due to mixing of migrants and generalist species of birds with the resident specialists and endemics. Wet evergreen forests and montane sholas, despite proving habitat to a number of specialists and endemic birds with greater conservation value, are comparatively less diverse in bird species than secondary / disturbed evergreen and moist deciduous forests (Daniels, *et al.*, 1991; 1992; 2001).

Human interference of forests has led to the disappearance of birds locally in the W.G. However, when large landscapes are considered, the avifauna has remained stable during the past 100 years (Daniels *et al.*, 1990a). Bird diversity is inversely related to woody plant species diversity (Daniels *et al.* 1992). Monocultures may support an assemblage of birds as diverse as (or even more diverse than) evergreen forests. However, birds that inhabit the monocultures are often generalist habitat users drawn form a wide range of neighbouring habitats (Daniels *et al.* 1990b, Pramod *et al.* 1997). Hence, rain forests with climax vegetations assume significance.

A total of 313 bird species belonging to 17 orders, 54 families and 174 genera were recorded from 1972 to 1986, from 1990 to 1996 and from 1998 to date. Fifty five per cent are residents and thirty six per cent migratory (Fig 1). The migratory birds not

only arrive to Malnad from parts of oriental region but also from Russia, Siberia, Korea, Africa and West Asia (Chakravarthy, 1997). In Malnad species richness varied from season to season (Fig. 2) with 83% being terrestrial species (Fig. 3).

The value of Malnad as a reservoir of biological diversity is indicated by 32 bird species being sighted rarely. Birds belonging to the family Irenidae (Iora, Chloropses and Fairy Bluebird), the only family endemic to oriental region, is well represented in Malnad. The Malnad avifauna represents 100 species (30%) of forest birds and 134 (46%) of passeriformes. Like in W.G. in Malnad also forest tracts support twenty or lesser number of species. But these (eg. Lesser Kestrel, Rock Bush Quail, Blackheaded oriele, White-bellied Black woodpecker and others) are rare and of high conservation value. The monocultured, man-made plantations (eg. of exotic eucalyptus, acacia, etc.) support little bird life (less than 10 to 12 species, on an average) but mixed plantations support 34 species. Mixed bamboo forest tracts attracted ten to twelve more species than mixed teak forests in Malnad. Tree species attracting higher number of bird species is depicted in Fig.4.

How does bird community and guild attributes vary with elevation in the tropical rain forest of the W.G.? Does elevation and habitat quality relate predictably with change in bird community? To answer these questions, Shankar Raman and Joshi (2001) carried out a study in the evergreen rain forest of Kalakad-Mundathjurai Tiger Reserve (Tamil Nadu). Across fourteen sites, 250 bird species were observed and none of the measured vegetation parameters was significantly correlated to elevation, except for bamboo density that showed a positive correlation (Table 1). Bird species richness and diversity indices were significantly negatively correlated with leaf litter depth. There were no significant correlations between birds and vegetation. Although some variation in guild structure could be attributed to elevation, bird guild structure was maintained by species replacements along the gradient.

The lack of a definite species trend and variations in bird composition along elevation and vegetation composition in WGK has consequences for bird conservation in the region. Hill tops of WGK may be represented by a few bird species (eg. Osprey, Yellow backed sunbird), but these birds are not normally sighted along other gradients. So, to protect full complement of rain forest bird communities, areas at all elevations be conserved (Shankar Raman and Joshi, 2001: Chakravarthy, A.K., Pers, Obs., 2001).

Peoples practices and attitudes

By tradition, people worship and protect by sentiments birds like Peacocks (*Pavo cristatus*), Owls (*Athene brtama*), Pigeons, rodents, snakes, monkeys and langurs and a wide variety of herbs, shrubs and trees. These creatures stand deitification to several gods and goddesses, are known by a variety of names across Malnad. People derive multiple benefits from forests and harvest the resources in a way that renewability and generation capacity of the source is not affected. Patches such as *Gomala*

(Grazing lands), *Soppina betta* (green manure yielding patches for areca and coffee plantations) and *Devara kadu* (forest patches attached with religious sanctity) which were parts of virgin forests earlier, serve as refugia for birds and other animals. Similarly the scrub patches, barren uplands or lands of low economic value, often used as grazing lands, hold very few species but add to the biodiversity. For instance, barren uplands are inhabited by Ashy-crowned Finch-lark, Malabar crested Lark and Paddy field pipit. The mixed-farming situations in the plains of Malnad offer feeding sites for over 30 species, temporarily. The people have practical means of deriving benefits without affecting the conservation value of the habitats (Chakravarthy, 1997).

People's perceptions towards nature and natural resources are also reflected in the way the crops are cultivated. A majority of the rural population are subsistence farmers traditionally cultivating paddy, coffee, areca, etc. For instance, how the three cultivated cropping landscapes sustain birds, is given below:

Coffee plantations

Coffee (*Coffee arabica* and *C.robusta*) plantations represent the minimal modifiers of basic bird habitats in Malnad. Agribusiness is centred around coffee. Most planters have conservative attitudes and often do not abuse agricultural chemicals, nor fell the multitudiness species of shade trees that represent elements of tropical rain forests. In fact, coffee cultivation began over a century ago, when planters maintained patches of natural forest besides coffee estates. Coupled with this, the branching pattern of the coffee plant, where the branches embrace a thick overlapping canopy about 2 m high, provides food (arthropods mostly), nesting area and shelter for shade-living as well as shrubbery-living arboreal birds. Coffee planting and tending does not require intense human pressure throughout the plant growth period. Coffee plant alone supports nesting of more than twelve species and hold 50 to 60 species at a time. Coffee plantations are the main refuge for more than 30 species during migration (September to January).

Cardamom cultivated patches

Farmers in Malnad plant rows of cardamom (*Elettlaria cardamom Maton*) the Queen of spices along streams in valleys. These cultivated patches are preferred habitats for the Malabar Whistling Thrush, Little Spiderhunter, Spotted Babbler, Jerdon's Blackbird, Orange headed Ground Thrush, Paradise flycatcher, Woodpeckers and bulbuls. The use of these patches by birds is high as farmers to not disturb them nor use pesticides. This traditional system of maintaining coffee and cardamom plantations accrue many benefits to the planters, such as bio-control of pests and pathogens, soil and water conservation, soil fertility restoration and sustainable crop yields.

Paddy fields

Paddy (*Oryza sativa*) covers 33% of the cultivated area in Malnad. Farmers maintain rows of shrubs and/or trees at the bare field edges. These niches provide birds with

sites for shelter, food and roosting. The rice plants stays in the field for about five months and provide suitable habitat for 28 to 30 birds.

At seedling stage, the puddled paddy fields with sheet of water offer attractive feeding sites for sandpipers, plovers, rails, crakes, snipes and stints. The vegetative stage is inhabited by paddy field warbler, wagtails, chats, etc. In the crop maturing stages, mynas, swallows, wagtails, harriers, hawks, kites, owls, munias, bayaweavers, Red-headed bunting and warblers visit paddy fields. Throughout the crop herons, paddy bird or pond heron (*Ardeola grayii*) in particular and egrets, storks, Ibises, frequent the paddy fields. Mason and Lefroy (1912), Mukherjee (1971 and 1975) and Majumdar and Brahmachari (1987) reviewed the literature on bird predators and concluded that the activities of birds in paddy fields were highly beneficial and that birds played the role of biocontrol agents.

In Malnad, birds are encouraged to frequent paddy fields, as farmers do not use pesticides, fertilizers or deploy heavy machinery or mechanized farming techniques. Cultivated areas when compared to a number of primary habitats including forests have proved to be more species rich in birds (except fresh water marshes). Birds as Malabar Pied Hornbill (*Antracoeros coronatus*) considered rare in W.G. itself, can be sighted in good numbers in drier agricultural tracts of Uttara Kannada. Similarly Crested Hawk-eagle (*Spizaetus cirrhatus*) was sighted in an agricultural area bordered by remnant forest trees (Daniels, et al., 1991). So a balanced approach to the management and conservation of birds in cultivated patches is required.

The Forest tracts

Of 15.5 lakh ha in Malnad, 10% is forest, so that the way people use and manage forests has profound influence on birds. The rain forest is characterised by species of *Alstonia, Artocarpus, Dipterocarpus, Palaquium* (*Dichopsis*), etc. One widely distributed tree is *Mimusops elengi,* which especially attracts green pigeons (of species Ducula, Treron) to its fruits and is found in Sringeri, Agumbe and Kalasa. *Myristica dactyloides* (Myristicaceae) is encouraged at higher altitudes (> 1000 m) in Agumbe, Gangamoola, Kudremukh, Kalasa, Magundi and South Coorg areas and is well known for attracting birds.

In Chikmagalur, forests support more than 20 rare bird species (i.e. Shaheen Falcon, Lesser Kestrel, White-bellied Black woodpecker, Ashy Drongo, etc.). Over exploitation of forest resources has reduced the forest cover. For example, in Uttara Karnataka district, forest area has reduced from 8000 km^2 to 6000 km^2 in about ten years (Potter, 1996). In W.G. forests cover 27,000 km^2. Only 10% of forests can now be classified as dense with a canopy cover of over 80%. The rest is degraded. For Malnad, the corresponding figure is 7%. Forests in Malnad are degraded partly through excessive logging of teak and Rose wood., softwood tree species as *Bomgax, Evodia, Macilus, Alstonia, Artocarpus* and others for match wood and plywood industries and more seriously through a lack of regeneration. Without adequate regeneration, traditional

management using variation of selection system is not possible and the forest may be replaced by scrub land.

Lack of forest regeneration is attributed to three main causes : removal of fuel wood and small sized poles for building, trampling and grazing by cattle and loss due to fire. The last being the most important. If these unique forest tracts are destroyed, not only will the local population be deprived of fuel, green manure and a wide range of other forest products, but there will be no timber and the plant and animal genetic resources will be irrevocably lost to India. So in Malnad, biodiversity monitoring and conservation is the need of the hour. In this contest, the Western Ghats Biodiversity Network (NGBN), Center for Ecological Sciences, Indian Institute of Science, Bangalore monitored Biodiversity in Malnad involving 300 students and two dozen teachers. Each college studied a nearby village landscape about 25 km^2. This flexible and exploratory design rather than hypothesis - driven approach facilitated participatory monitoring of biodiversity that is very much required now-a-days. Along 20,500 m length transects, species richness and abundance of trees, birds, butterflies and ants were sampled (Kunte *et al.* 1999; Nagendra and Gadgil, 1999) after land use classification and mapping.

Human habitations harboured high bird diversity (Table 2). Management strategy should focus on maximizing total biodiversity value of the mosaic of habitat types within the landscape (Pramod *et al.* 1996b). For instance, nurturing of keystone specie like Figs (*Ficus* sp.) is both socially appealing and biodiversity friendly (Utkarahs and Almeida, 1999). Likewise in Malnad, species of *Ficus, Carya, Erythrina, Butea, Bombax* and *Lagerstromea* attract 6 to 9 families of birds (Chakravarthy, 1997). These tree species also hold other animal taxa.

Gap analysis programs have been used to determine biodiversity hot spots, identify gaps in existing protection and for conservation prioritization (Jennings, 2000). Unfortunately, detailed inventories in field are constrained by severe resource and time limitations. Alternative strategies for collecting biodiversity data include vegetation analysis of satellite imagery and spatial analysis of existing and future landscape changes (Menon *et al.* 2001).

Conservation and Management

Given the foregoing background for the status of natural resources particularly birds in Malnad, following actions are worthy of implementation.

The Wetlands

The wetland habitats in Malnad-streams, river beds, estuaries, ponds, lakes, water beds, marsh are interlinked forming a network which constitutes a complex ecosystem, where plants, animals and people are interdependent. The main environmental issue concerning wetlands in Malnad are excessive growth of vegetation and weeds, reduction in water clarity, enrichment of waters, siltation and high microbial activity (Chakravarthy

and Sridhar, 2000).

a. In Chikmagalur, Hassan, Coorg and Shimoga, coffee pulping and areca curing waste waters are entering into river streams and have polluted much of the natural net work of wetlands. For instance in Bhadra wild life sanctuary, Somvahini river is the only source of water for the people of the forests. Coffee planters surrounding the sanctuary drain water from the pulper units into river stream, polluting the entire river system. Curing centers are not adopting environmental safety norms. Gangamoola, the source of several rivers including Bhadra is located 11 km from the new area prospected for lease by the mining company. What effect mining and ore extraction activities will have on avifauna is yet to be ascertained. The coffee pulper waste waters need to be diverted to pits underground and areca curing waters need to flow in broad channels, thus exposing for natural cleaning processes.

b. Silting and sedimentation problems need to be addressed immediately. All cultivation, brick making and mud lifting activities around wetlands are seriously affecting wetland ecology and biodiversity. These activities have affected more than 100 wetlands in Malnad. Arasikere - Alampura, Ambelekere tanks in Chikmagalur, Bhuvasamudra and Sigadikere in Coorg and Purale and Navile tanks in Shimoga district are instances of such onslaught on water bodies.

   The afforestation of catchment areas of wetlands will not only help in preventing silting, meet the biomass needs of the local people but also enrich productivity/ biodiversity of the habitats. Trees like *Acacia nilotica, Casuarina equisitifolia, Dalbergia sissoo, Ficus glomerata, Lalgerstromia speciosa*, species of *Pongamia, Popullus, Myristica* and others can be planted at different strata, layer by layer, depending on the ability of the species to withstand flooding, inundation, dry conditions as the case may be for afforestation. Proper landscape improvement in ecological terms for catchment and shore areas need to be adopted.

   Major pockets and habitats associated with large populations of birds like Gudavi and Mundagadde in Shimoga, Alur and Madenur tanks in Hassan and Iyyankere and Karaghattakere in Chikmagalur need to be cleaned-up, provided with more perches for shelter and nesting of herons, egrets, cormorants and shorebirds like plovers, sandpipers, lapwings, etc.

c. Lakes and ponds in and around all major towns like Sakleshpur, Madikeri, Hassan, Chikmagalur, Belur are becoming boggy with green and brown algal blooms. Most of these water bodies have lost seasonality and wetland values. For surface feeders like teals, spot billed ducks, Coots, Dabchicks and Piscivorous species like cormorants it has become difficult to adapt to turbid waters. Owing to proximity to industries, urbanized set-up, fertilized fields and other sources of pollution tanks are turning to eutrophic ecosystems and there is a need to arrest tanks from these processes.

d. Poaching and hunting of birds is prevalent in 18 tanks in Hassan, 11 in Coorg, 29 in Chikmagalur and 19 in Shimoga. Conflicts between waterbirds and man has increased especially in wetlands leased out to harvest fishery resources.

e. Fishery resources in most of the river streams is too low to support the waterfowl and aquatic avifauna. For insance in Chikmagalur in Tunga, Bhadra, Hemavathi, Yagachi, Veda, Avati, Nethravati, etc. river streams annual fish catches are too low for sustainable harvesting. So fishing should be prohibited in important sections of river streams. For instance, the Coorg wildlife society, Coorg, banned fishing in 25 km stretch of Cauvery river in Shuntikopa and this resulted in the retreatment of the prized fish, the Mahasheer and rare species of water birds like Green heron, Large egret, etc.

The protected Areas

a. Effective management is the responsibility of the protected area management staff. A reduction in the total area of the ecosystem reduces species diversity until it reaches an equilibrium of the size of the ecosystem. The case in point is that of the Kuvempu Biosphere reserve, Kuppalli, Thirthahalli, Shimoga. Of 6866 acres, only 3230.50 acres has been declared as Biosphere reserve. Over 2336 acres adjoining to the Biosphere reserve has remained as revenue lands and over 1,300 acres as minor forest area. So the Government of Karnataka should extend the Biosphere reserve and enact gazette of all remaining areas.

b. Ecotourism in developing countries like India with tropical forests has become big business. The growing demands for ecotourism should present numerous opportunities for increasing sustainable, rural and national development, while still protecting biodiversity. For instance in Kuvempu Biodiversity Park, few cottages and thatched huts should serve the purpose of researchers, ecotourists and environmentalists. Uncontrolled tourism development and impacts can degrade the sustainable and scenic resources of the park.

c. Traditional cultures in and around protected areas, sanctuaries have evolved practices over the year to promote sustainable use from the conserved natural resources. But the same practice has just the opposite effect as population begins to increase rapidly. The survival strategies of the poor particularly, their search for food, fodder, fuel and shelter often lead to over-exploitation of natural resources, accentuating environmental degradation (Fig. 5). This is the situation particularly in Bhadra wildlife sanctuary, Chikmagalur and Nagarhole National Park in Coorg. In the former, in 24 villages inside the sanctuary, the human population has increased four folds in the last two decades and people inside the sanctuary are not interested in the forests, natural resources. In Nagarhole park, the clashes between the tribals inhabiting the sanctuary and the Forest officials have increased by many folds. There should not be delay in the resettlement of inhabitants outside the sanctuary/park and people should not be allowed to cultivate the land inside the sanctuary/park.

d. The entire sanctuary/park should be under the control of one District Forest Officer (DFO), under one Division.

e. In Malnad, considerable forest area, particularly the shola forests are under the Revenue Department and the encroachment into forest area is rampant. All these lands are very crucial for the sustenance of the sanctuary and should be under the control of Forest Department. The Government Forest policies are being implemented but implementation is tardy with deficiencies. Poaching and hunting activities are rampant during night. The number of guards/watchers are too low. Even those that are present are working 'hand-in gloves' with poachers and smugglers. So monitoring and strict vigilance are urgently required in all the protected areas in Malnad.

f. River systems of protected areas are being increasingly polluted. The pollution Control Board should keep a strict vigilance and sustain clean waters.

g. In protected areas, there should be a close and good co-ordination among the various Government Departments like Revenue, Electricity Board, Forest, Police, Environment, Water and Sewerage Board, Animal Husbandry, etc. This is lacking in almost all the protected areas.

h. Wild life habitat fragmentation and destruction should be halted, cultivation and timber extraction should not be permitted within 10 km^2 of the protected area.

i. Buffer zones need to be created around all the protected areas in Malnad.

The Forests

The eight districts of WGK have 70.8 per cent of the forest area, which is 38.3 per cent of the state geographic area. As a percentage of the total geographic area of these eight districts, 32% is reserved forests which are governed by law, where grazing is regulated, fuel wood collection is controlled and restricted to dead wood. In such forests the man-animal conflict is minimum and bird diversity is maximum. Such forest tracts support even nesting of top consumers like black eagle, *Ictinaetus malayensis* Shaheen falcon, *Falco peregrinus* and owls of several species.

Unfortunately important forest areas such as Magundi, Hebbe forests, Kaiga, Jagar valley, Kalasa, Kemmangundi and Kudremukha have been alienated to non-forestry uses. Mines and hydroelectric installations have made significant contributions to the economy but with an accompanying loss of over 2,00,000 ha of state forest land. A further 50,000 ha have been allocated for cultivation, rehabilitation of displaced people and other purposes. In addition, 24,500 ha of the W.G. forests have been subject to encroachment by cultivators. Control of encroachment is made difficult where boundaries are not marked. Grazing today is unrestricted and unregulated. Firewood collection is widely extended to the cutting of live material such as saplings and small poles. Fire is widespread during summer in the deciduous forest types and in the grassy areas within the forests. The result today that reserved forests are in serious decline, land outside forests is degraded and no longer meet the requirements

of local people.

To ameliorate the crisis, Joint forest Planning and Management (JFPM) and Village Forest Committees (VFCS) have been formulated and implemented. Efforts have been made to identify the biodiversity hot spots in different forest types. Threatened habitats have been identified and multiple native species of planting trees have begun. Permanent monitoring plots have been established. In such habitats many native species have been retreated. The forests of W.G. need to be managed on sustainable basis. Following measures are required to restore forests of W.G.

a. Restoration of highly degraded forests.

b. Improved management of less degraded forests like bamboo, cane, sandalwood, timber and non-timber forests management.

c. Farm forestry and agro-forestry for extending tree cover in areas outside forest lands.

d. Supply and installation of energy saving devices.

e. Maintenance and improvement of the existing protected areas network.

f. Strengthening of Forest Department capabilities for forest protection such as increasing number of watchers/guards and rotating them in each locality.

g. Relief or reduction of man-animal or bird conflict around protected areas.

h. Inventory of forest resources and establishment of information systems.

i. Training of forest personnel, extension services for NGOs, communities.

Earlier, forest protection, timber production, afforestation and consolidation of the forest area from encroachment were the main concerns of the forest department. Now, the management priority has been focused on the conservation and protection of forest resources for their environmental benefits. The policy of the Forest Department now is to protect and conserve forests involving local people and NGOs through participatory processes.

The cultivated tracts

In Malnad, about 60% of workers are engaged in agricultural fields. The per capita agricultural land is 0.22 ha with an average area of 1.66 ha. The average size of farm holdings is only 1.16 ha. Small (i.,e. 1-2 ha) and marginal (less than 1.0 ha) land holdings account for 76.1% of the total number and 36.3% of the total area of farm holdings in W.G.K. This is indicative of the small farm based economics of the Western Ghats region and consequently the need for other income sources to supplement the low income derived from farms. The considerable areas given to permanent/perennial cash crops accentuate the problems associated with the small area of land available for food crops. On the western and central portions of Ghats, there are 1,00,000 ha of coffee estates, 56,000 ha of areca gardens, 37,000 ha of

cashew, 31,000 ha of cardamom and 50,000 ha of coconut plantation. As a result, the land available for food crops is very low. Because of the wide fluctuations in market price of these products, farmers approach to farming is 'sustainable agriculture', which is a balanced approach. So crop production should be more balanced considering the biodiversity this unique ecosystem holds. Forman and Godron (1986) have introduced some fundamental principles related to biodiversity conservation in fragmented habitats. The cultivated fields, both natural and cultivated, interspersed with corridors, ecotones and water courses should be hedges/tree-line or shrubs at borders, should not use often broad-spectrum pesticides, heavy machinery and should encourage insectivorous birds by providing sufficient perches, shelter/nesting sites, food alternatives and roosting sites.

Summary

The Malnad in Western Ghats (W.G.) region of Karnataka represents one of the world's 25 mega diversity hot spots and Western Ghats is home for 350 endemic plants, 324 vertebrates and nearly 400 bird species. The bird diversity is declining in Malnad because of increases in human and livestock populations and consequent pressure on forest for non-forestry purposes. By tradition, people are conscious of conservation and maintain sustainability and renewability of natural resources. The development programmes like construction of dams, mining, roads and huge building constructions should not jeopardize this activity of the region.

The full complement of rain forest bird communities along the gradient of W.G. need be conserved. Coffee, Cardamom, paddy and other crop's patches should continue to hold higher bird diversity. Joint Forest Management and Village Panchayat committees should ensure forest conservation via soil and water conservation measures, agro-forestry and farm forestry practices, improvement of protected areas network and by reducing man-animal conflicts. Protection to bamboo patches, preventing silting, sedimentation and encroachment of wetlands and forest patches and hunting and poaching of birds through peoples participation is important. Protection of forests from fire is a critical factor for bird conservation and diversity in Malnad. Bird diversity in mosaic of cultivated patches should have characteristics to hold endemic as well as migratory birds. In all, biodiversity in Malnad is declining and concerted efforts to preserve diversity is urgently needed.

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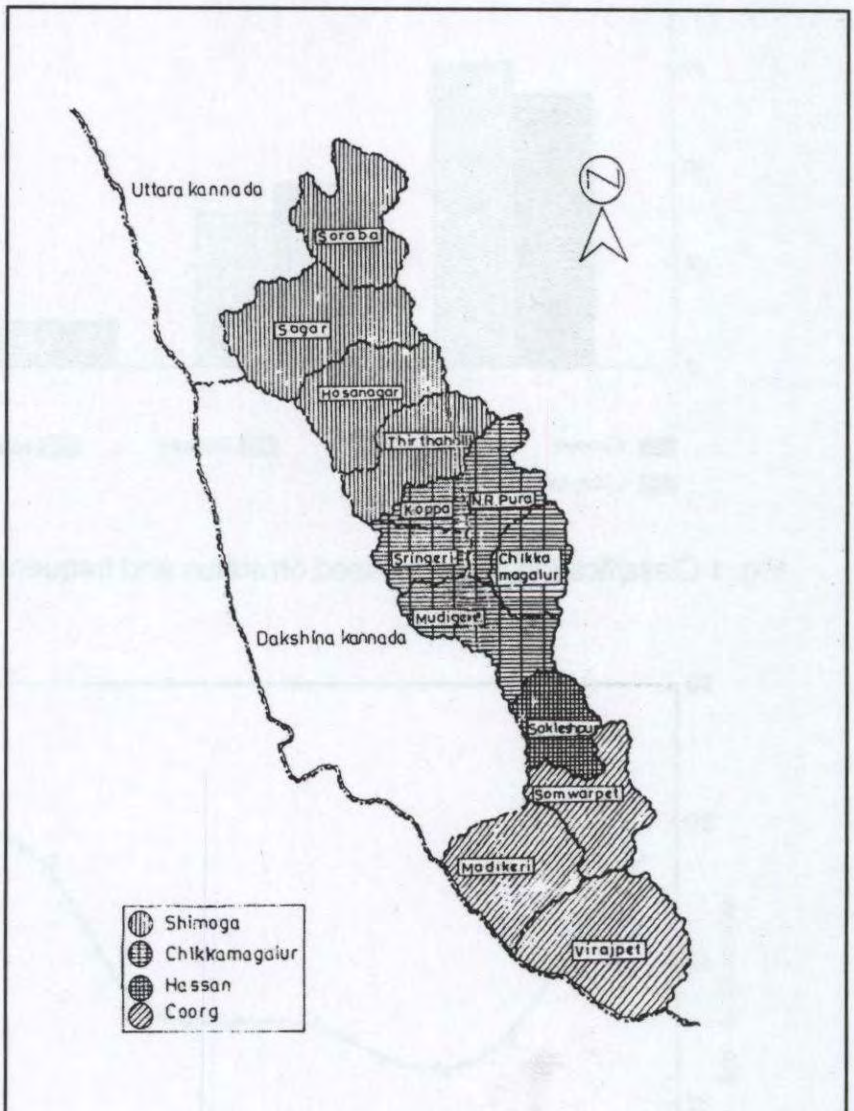

A Map of four Districts in Malnad

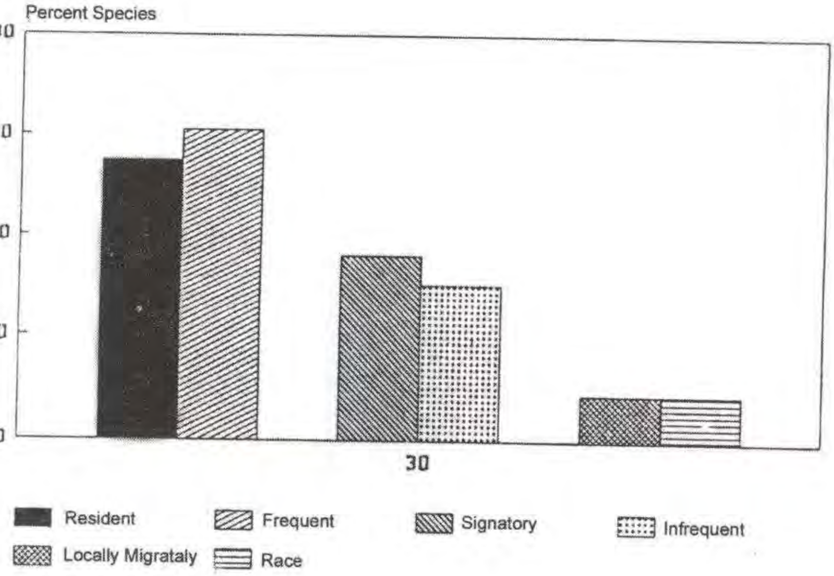

Fig. 1 Classification of birds based on status and frequency of occurence

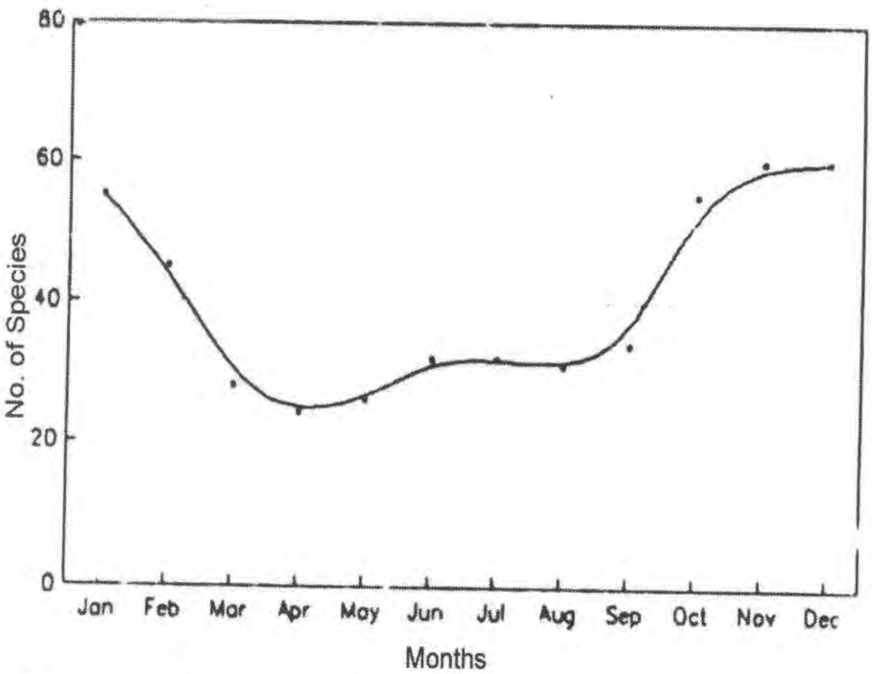

Fig. 2 Seasonal fluctuatin in Bird species

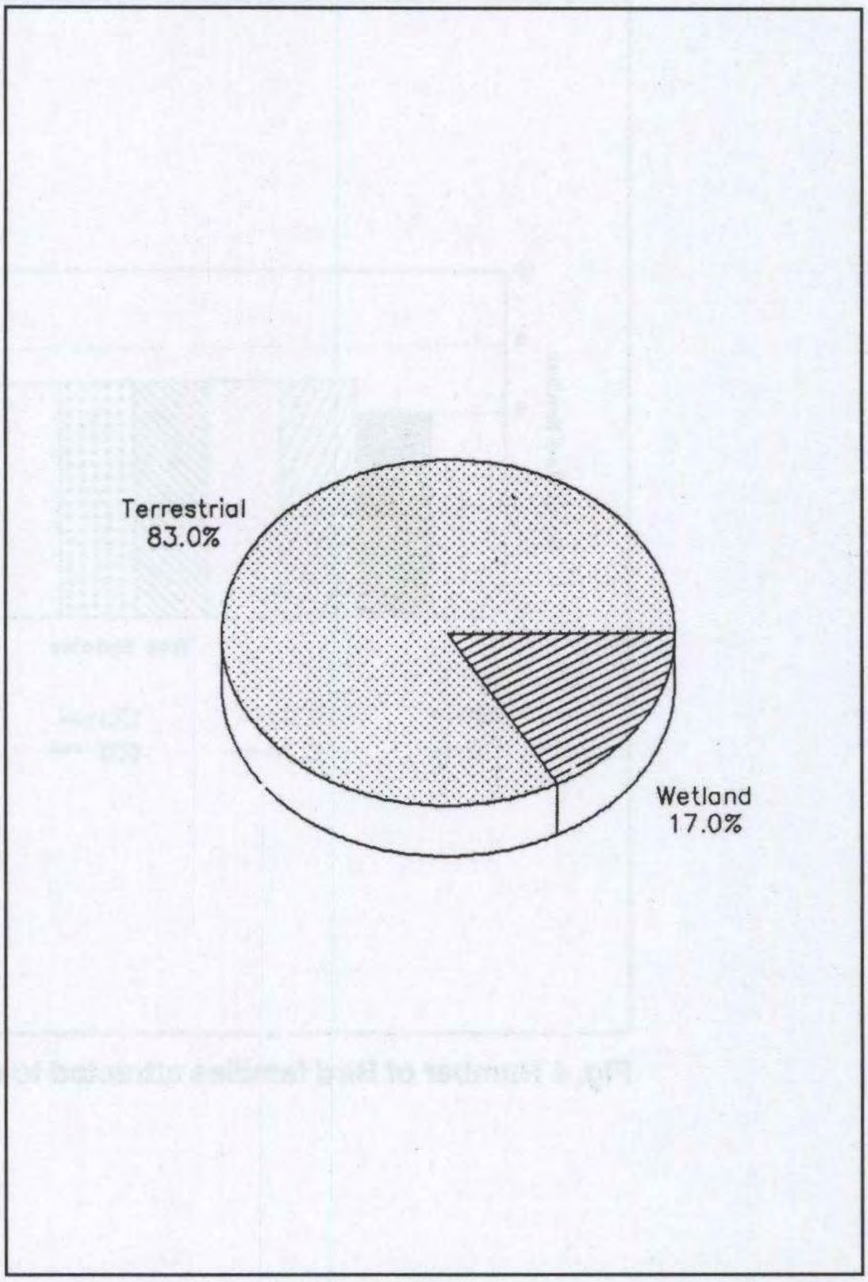

Fig. 3 Number percent of bird species inhabiting Terrestrial and Wetland eco systems

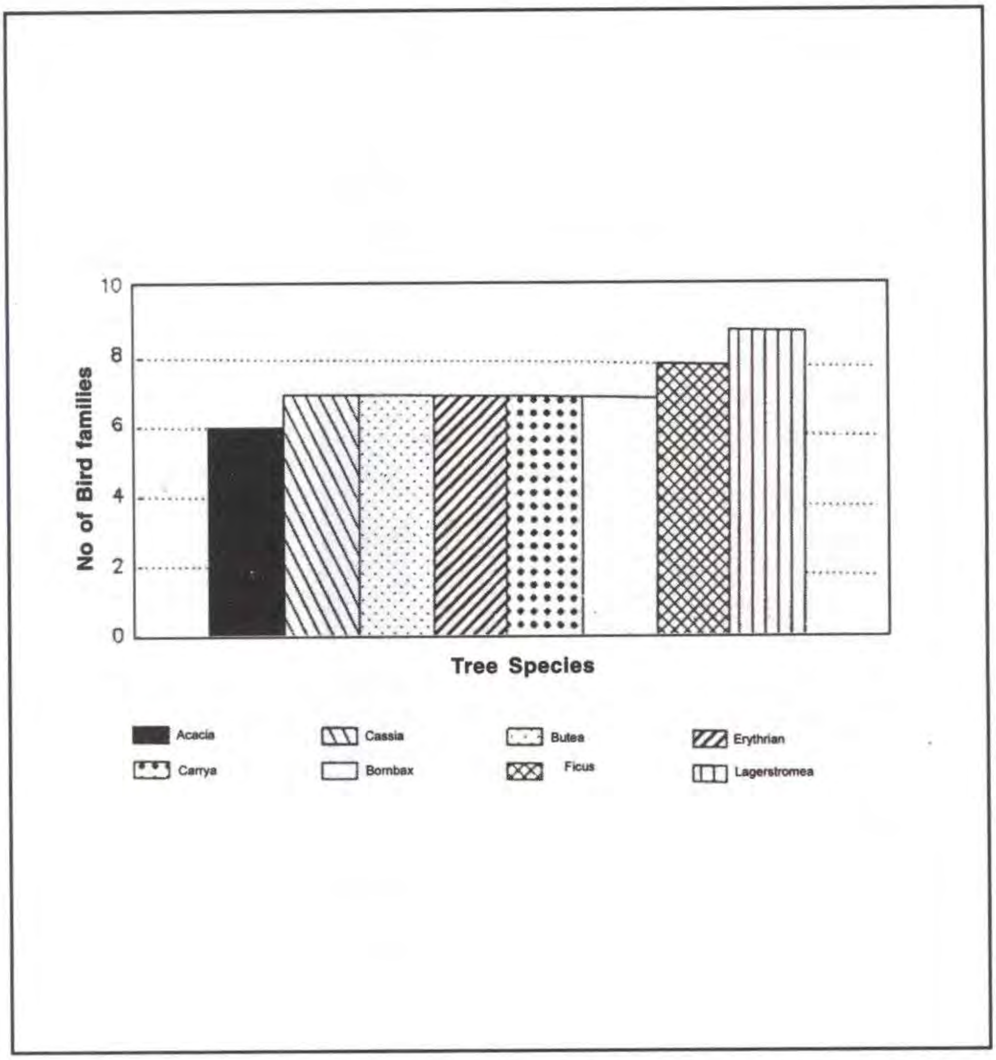

Fig. 4 Number of Bird families attracted to different tree species

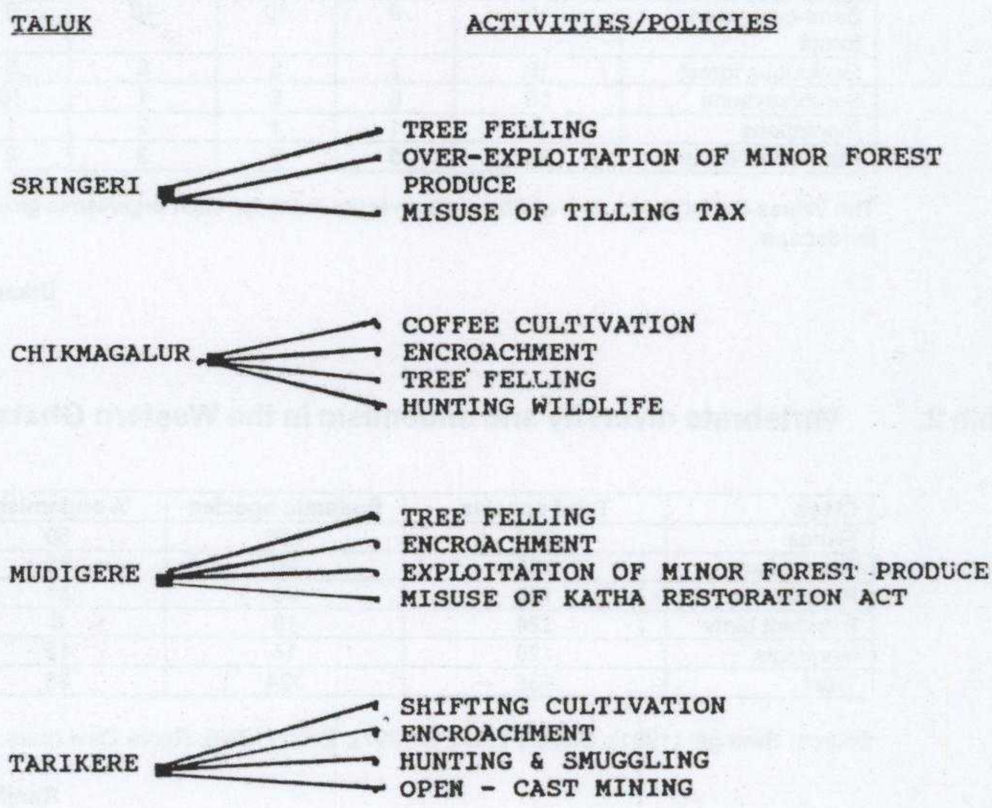

Fig. 5 Policies/activities interfering with natural resources management in selected taluks of chikmagalus district

Table 1. Covariation in biodiversity values across organismic groups and vegetation types.

Vegetable type	% area of landscape	Trees (a)	Birds (b)	Butterflies (c)	Ants (d)	Total (a+b+c)
Evergreen forest	5	10	7	5	9	31
Semi-evergreen forest	10	9	10	10	8	37
Deciduous forest	10	7	5	6	5	23
Scrub/savanna	15	6	6	1	10	23
Plantations	15	1	1	2	1	5
Human habitations	30	5	8	3	2	18

The values depict mean rank of Shanon's diversity index for each organismic group per type per landscape.

Utkarsh et al. (2001)

Table 2. Vertebrate diversity and endemism in the Western Ghats

Class	Total species	Endemic species	% endemism
Fishes	218	108	50
Amphibians	120	90	75
Reptiles	156	93	54
Resident birds	324	19	6
Mammals	120	14	12
Total	938	324	35

Source: Swengel (1991); Daniels (1992 & 1997); Easa (1998); Rema Devi (pers. Comm.)

Ranjit Daniels (2001)

Chapter 13

TROPICAL RAINFORESTS OF INDIA: REVIEW OF SCIENTIFIC RESEARCH ON VERTEBRATES IN THE PAST 30 YEARS

R J Ranjit Daniels

This paper is not intended to be an in-depth review of scientific research on vertebrates of tropical rainforests in India. Instead, the paper attempts to highlight

- The various categories of scientific research on vertebrates carried out in Indian rainforests,
- The relative importance given to the different categories of scientific research,
- The geographical spread of the scientific research,
- The major institutions involved,
- The apparent gaps and
- The scope of future scientific research.

Tropical rainforests, by strict definition, are rather limited in extent in India being restricted to the Western Ghats southwards from Goa, the Andaman and Nicobar Islands and some pockets in the northeast. Even here, due to human influences (both past and present), altitude (low, medium and high elevations) and local climatic variations (especially length of dry season) the tropical rainforests vary considerably in structure and function that we find them as elements of extensive vegetation mosaics in highly heterogeneous landscapes.

Difficulties arise not only in defining the limits of rainforests but also in classifying vertebrates as rainforest specialists and generalists. This however does not suggest that there is no vertebrate that is strictly a rainforest specialist. It only highlights, amongst other things, the need to provide appropriate and more widely accepted working definitions to an array of ecological nomenclature related to habitat use. While such definitions by themselves can be the focus of intellectual debates and discussions, my paper does not make an attempt to do so.

The following table highlights scientific research on the 5 vertebrate classes *viz.*, fishes, amphibians, reptiles, birds and mammals, in tropical rainforests of India since 1970. It also provides insights on how these studies have been distributed amongst the rainforests of the Western Ghats, Eastern Himalayas and the Andaman and Nicobar Islands. Major institutions involved in each region have also been listed.

Vertebrates Class	Nature of Scientific Research	Western Ghats	Eastern Ghats	Andaman and Nicobar Islands
Fishes	Taxonomic	ZSI, KFRI, Manonmaniam Sundaranar University	ZSI	ZSI
	Surveys	ZSI, BNHS, SACON, Manonmaniam Sundaranar University, Madurai Kamaraj University, Salim Ali School of Ecology, Karnataka University	ZSI, Guwahati University, NEHU	ZSI, CARI
	Ecological	CES/IISc, Manonmaniam Sundaranar University		
	Genetics and Conservation	NBFGR, CMFRI		
Amphibians	Taxonomic	ZSI, BNHS, Karnataka University, Kuvempu University, Mangalore University, Utkal University, Natural History Museum (New Delhi), Field Museum of Natural History (Chicago)	ZSI	ZSI, Madras Crocodile Bank
	Surveys	ZSI, BNHS, Karnataka University, KFRI, Kuvempu University, Mangalore University, Bangalore University, Natural History Museum (New Delhi), Field Museum of Natural History (Chicago)	ZSI, NEHU	ZSI, Madras Crocodile Bank, BNHS
	Ecological	CES/IISc, SACON, WII, Field Museum of Natural History	NEHU	
	Genetics/ Physiological	Mangalore University, Karnataka University, Bangalore University		

	Captive Breeding Conservation	CES/IIsc, Coimbatore Zoo		
Reptiles	Taxonomic	ZSI, Chennai Snake Park, Madras Crocodile Bank, SACON, KFRI, BNHS	ZSI, BNHS	ZSI, Madras Crocodile Bank
	Surveys	ZSI, Chennai Snake Park, KFRI, Madras Crocodile Bank, BNHS, SACON, Mangalore University, Pune Serpentarium, Natural History Museum (New Delhi), Field Museum of Natural History (Chicago), WII	ZSI	ZSI, Madras Crocodile Bank
	Ecological	WII, Natural History Museum (New Delhi), Field Museum of Natural History (Chicago), Mangalore University		Salim Ali School of Ecology
	Captive Breeding Conservation	Forest Departments		Madras Crocodile Bank
Birds	Surveys	BNHS, ZSI, SACON, Calicut University, KFRI, Kerala Agricultural University, Tamil Nadu Agricultural University, Forest Departments, several bird watchers, NGOs	BNHS, ZSI, Guwahati University, Birdwatchers , NGOs	BNHS, SACON, ZSI, Birdwatchers, NGOs
	Ecological	BNHS, Calicut University, KFRI, CES/IISc, Karnataka University, SACON, Salim Ali School of Ecology (Pondicherry), WII and a few foreign universities	BNHS, Guwahati University, WII	SACON, BNHS, Salim Ali School of Ecology Pondicherry
	Behavioural	BNHS		SACON, BNHS
	Conservation	CES/IISc, SACON, BNHS		SACON, BNHS
Mammals	Surveys	ZSI, BNHS, WILL, KFRI, CES/IISc, SACON, Forest Departments, U. Karanth, Mysore (NGO), Madurai Kamaraj University, Mysore University	ZSI, BNHS, WII, Guwahati University	ZSI, SACON
	Ecological	CES/IISc, KFRI, SACON, WII, Salim Ali School of Ecology, AVC College (Mayiladuthurai), BNHS, Mysore University	WII, BNHS, NGOs, Guwahati University	SACON
	Behavioural	Mysore University, CES/IISc, KFRI, Salim Ali School (Pondicherry), WII, Foreign Universities, BNHS, AVC College (Mayiladuthurai), Madurai Kamaraj University, Mysore University, Ukaranth/ Mysore - NGO	WII, Guwahati University	

The above table is more indicative in nature than exhaustive. There are several MSc, MPhil and PhD dissertations lying in university libraries throughout India wherein one or more of these aspects have been covered during the past thirty years. Unfortunately, very little is known of these documents. Similarly, throughout the region, the State Forest Departments have conducted many surveys from time to time, especially of birds and mammals, the results of which are rarely made available to the public.

The year 1972 is very important in the history of biodiversity conservation in India. Nationwide efforts to conserve India's biodiversity started with the Stockholm Conference on Environment and Development in 1972. Close on the heels of this international conference in which India actively took part, the Wildlife (Protection) Act, 1972 came into existence. Since then, research and management of wildlife (vertebrates in particular) in India has been guided largely by the Act. It is therefore appropriate to review scientific research on tropical rainforest vertebrates during the thirty years since the Act.

At a glance, the table suggests that most research has been in the Western Ghats. Major gaps exist in the Andaman and Nicobar Islands and in the northeast. In general, scientific research on rainforest vertebrates is dominated by a few well funded and government aided institutions. Serious efforts should be made to support local colleges and NGOs in undertaking research in tropical rainforests. While such interest exists in ornithological research, other classes of vertebrates are largely lagging behind. Initiatives such as the Western Ghats college/University Teachers' Networks should be encouraged to go beyond surveys and para-taxonomy and carry out more ecological and conservation research. Such initiatives should be launched in the other areas too.

Database and simple field guides to the vertebrate fauna of the rainforests will go a long way in strengthening field research in ecology and conservation - both sciences being generally impoverished in India. While there are guides to birds, few exclusive guides exist for the other classes. Serious efforts should be made to bridge the gap between taxonomists and field biologists interested in studying tropical rainforest vertebrates other than birds.

Abbreviation

ZSI	:	Zoological Survey of India
KFRI	:	Kerala Forest Research Institute
BNHS	:	Bombay Natural History Society
SACON	:	Salim Ali Centre for Ornithology and Natural History
CES	:	Centre for Ecological Sciences
IISc	:	Indian Institute of Science
NBFGR	:	National Bureau of Fish Genetic Resources
CMFRI	:	Central Marine Fisheries Research Institute
NEHU	:	North Eastern Hill University
WII	:	Wildlife Institute of India

Plate 5

Rainforest Fragments in the Munnar : S.U. Saravana Kumar

Wild Fungus in Tenmalai : S.U. Saravana Kumar

Chapter 14

INTRODUCTION OF THE ANAMALLAI BIODIVERSITY CONSERVATION ASSOCIATION

Simon Vasnaik

- Introduction
- Main objectives of the Association

Introduction

The Anamallai Biodiversity Conservation Association (ABCA) is an environmental NGO at Valparai, registered under the Societies Act on 06.11.2000 at the Office of the Sub-Registrar, Tiruppur. It is based on the objectives of the High Range Wildlife & Environment Preservation Association at Munnar and the Megamallai Wildlife Association at Megamallai Hills, Periyar.

It consists of 35 members from all walks of life and anticipated to reach 100 in coming few months. The membership is of 3 categories - Life, Ordinary and Student. It is represented by a 10 member Executive Committee with Mr. D.G.Hegde as Chairman.

The aspects of Valparai include:

1. About 13,000 Ha. of plantations of Tea, Coffee, Cardamom, Vanilla and Pepper on the Western slope of the Anaimudi started in 1897.
2. The Indira Gandhi Wildlife Sanctuary of about 950 Sq. k.m. declared as sanctuary in 1976. An area of 108 Sq. km. was declared as National Park in 1989 in the Grass Hills region. This Association operates in the Valparai and Manamboli Ranges of the Sanctuary.
3. Watershed - The Parambikulam-Aliyar Projects consists of 5 dams of about 6500 M. Cusecs capacity, 18 km. of tunnels and 49 cu.m. of open canal.
4. Township - The population is about 1 lakh and the Township Panchayat has an annual revenue of about Rs. 5 crore.

The main objectives of the Association are:-

1. Preservation of wildlife in the Anamallais and their habitat.
2. Promote awareness on conservation
3. Facilitate research
4. Compliment other NGO's on Environment and Tribal welfare.

1) Preservation of wildlife in the Anamallais and their habitat:

To achieve this, the followings are implemented:

a) Honorary Wardens - Honorary Wardens have been nominated from different zones in the concerned area of Anamallais Hills to report on any activity.

b) Shola re-generation - A biodiversity model plot was done by M/s Hindustan Levers Limited by identifying an inventory of flora species in a jungle shola and introducing other forest species to regenerate the forest.

c) Forest Corridors - It is proposed that sholas should be regenerated in vacant swamps within plantations to provide a corridor for migrating populations of animals. This will also reduce the need of elephants to approach human inhabited sections and avoid man - animal conflict.

d) Support the Forest Department - Man & Animal conflict, wildlife protection etc. are issues that require the plantation community to support the Forest Department. This Association proposes to serve as a link to this process.

e) Conservation - Conservation of soil by encouraging afforestation, construction of revetments in the cultivated areas etc.

The following activities are proposed:

(a) Forest fragments should be preserved against firewood collection, clearing and cattle grazing.

(b) Water sources and streams should not be disturbed.

(c) Endemic species should be protected with greater attention as their population is unique to a restricted region only- such as the Lion Tailed Macaque, Brown Mongoose, Brown Palm Civet, Nilgiri Thar and Nilgiri Langur are endemic to the Western Ghats of South India.

II) Promote Awareness on Conservation:

The following steps are undertaken/proposed:

a) The Association has arranged presentations by Ms. Cheryl Nath on "Man and Animal Conflict" and by Mr. Shankar Raman on "Rain Forests". Many more such programmes are planned.

b) It is proposed to hold painting/quiz competitions in the schools on "Environment".

c) Sale of World Wide Fund (WWF) Products - Jackets, bags, cards, calendars, caps etc. of WWF were sold to collect contributions.

d) Members have taken part in the Wildlife Census conducted by the Forest Department. Outdoor Treks are planned in the dry weather for members and students, including bird watching to Grass Hills and Manamboli areas etc.

e) Anti-litter and pollution programmes - Posters and awareness programmes on anti-plastic and litter disposal are proposed, as Valparai is an environmentally sensitive region of high bio-diversity.

f) Distribution of theme based newsletters are proposed.

III) Facilitate Research

The main research projects identified relates to the preparation of Inventory of Flora and Fauna, Migration and Animal behaviour studies. Plantation ecosystems are other main issues that the Association wishes to facilitate Researchers to study. Other few major research aspects especially from local peoples perspective are on alternate sources of fuel for domestic use (gas) instead of firewood, sources of packaging material/building material instead of wood etc.

IV) Compliment other NGO's on Environment & Tribal Welfare

The Association would compliment other NGO's in work beneficial to the environment and tribal welfare in the concerned region.

(Presented by Mr. Simon Vasnaik at the Workshop on Tropical Forests at Coimbatore on 27th & 28th February 2001)

Chapter 15

STUDY OF GENETIC DIVERSITY

P.T. Cherian

- Introduction
- Tasks Ahead
- References

Introduction

Species and regions differ in their number of populations. Surveys using electrophoresis have ranged widely over many kinds of organisms. Of all the discoveries made, one stands out: the amount of genetic diversity revealed is very large, much greater than had been expected in pre-electrophoresis days. In order to express the diversity as a number, geneticists use the concept of polymorphism. A gene is said to be polymorphic when it occurs in multiple forms or multiple alleles. In the great majority of species, somewhere between 10 to 50 percent of genes are polymorphic. A typical figure is roughly 25% (Wilson, 1992).

High levels of polymorphism per gene through the population also produce high levels of polymorphism within the bodies of individual organisms. On an average, between 3 to 20 % of the genes in each individual (depending upon the given species) are polymorphic. This means that each organism is heterozygous for that number of genes.

Population of a given species, if defined on the basis of a limited gene flow among them, will evolve to an extent independently. Each population contributes additional diversity. The number of genetic populations in the world has been estimated to tie between 1.1 and 6.6 billion (Hughes et. al. 1997).

Species and populations differ in the numbers of alleles they have at given loci. For instance, Mauritius kestrels (*Falco puntatus*) have lost over half of the alleles present historically at 12 sampled microsatellite loci (Groombridge et. al, 2000). Some pairs of species (or alleles or populations) are very alike, whereas others are very different. Disparity and character diversity are measures of phenotypic difference among the species in a sample and can be made independent of species number. Some phenotypic characteristics might be considered more important than others, for instance the ecological diversity among species may be crucial for ecosystem functioning. Genetic variability among populations within species differ enough either genetically or phenotypically, they may be considered to be subspecies, management units or evolutionarily significant units. Numbers of these units therefore provide estimates of differences are likely to be at least partly reflected by the phylogenetic diversity, among organisms, which is estimated as the sum total of the branch length in the phylogeny (evolutionary tree) linking them.

Tasks Ahead

Fortunately in the areas of study of species diversity, India's achievements can be compared favourably with that of many advanced countries of the world. While advances have been made in the study of alpha taxonomy of species, tremendous efforts are called for in the areas of genetic and ecosystem diversities in India. In the sphere of genetic diversity India is yet to make a proper beginning. But for some cursory studies conducted by a few institutions, there is not much worth mentioning. In these spheres we are far behind many other countries, including even a few developing ones.

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Plate 6

Bunopithecus hoolock: A.K. Gupta

Slow loris (Nycticebus coucang): A.K. Gupta

Chapter 16

CONSERVATION OF POLLINATOR SERVICES IN RAIN FORESTS

Renee M. Borges

What escapes the eye, however, is a much more insidious kind of extinction: the extinction of ecological interactions.

Daniel Janzen, 1974

Introduction

In the current rush to conserve the biological diversity of this planet, most attention is being paid to species inventories with too little attention to the ecological role of these species. This is understandable because of the perception of great threat to natural habitats throughout the world. However, unless there is insight into the contribution of particular taxa to ecosystem function, prioritization of conservation efforts and even better directed efforts at conservation would be impossible. It is pragmatic to expect that certain taxa will gain more acceptance as conservation targets if they are found to be invaluable to human existence. This is why when conservationists estimate that a bee, butterfly, bat, bird, or other pollinator is responsible for 1/3rd of all foods consumed by humans (Ingram, Nabhan and Buchmann 1996), this should be sufficient cause for strong lobbying for the protection of pollinator services.

Greater than 30 animal genera consisting of hundreds of species pollinate the 100+ crops that feed the world (Prescott-Allen and Prescott-Allen 1990). Only 15% of these crops are serviced by domestic honeybees while 80% are pollinated by wild bees and other wild organisms. Animals provide pollination services for over 75% of all the world's staple crops and for 90% of all the world's flowering plants (Buchmann and Nabhan 1996). Constanza *et al.* (1997) estimate that annual services due to pollinators is worth $112 billion. Another independent estimate rates the value of pollination services for global agriculture at $200 billion (Richards 1993). Honeybees are believed to pollinate $10 billion worth of crops in the USA annually (Watanabe 1994). Considering this widespread dependence of wild plants and crops on pollinators, it is therefore natural for concern to be exhibited when these ecosystem services are perturbed. For example, in the USA, the number of commercial bee colonies declined from 5.9 million (1940s) to 4.3 million (1985) to 2.7 million (1995) (USDA Report).

This paper will examine the problem of pollinator declines and will attempt to view the following questions globally and then locally for India: Are pollinator declines a real phenomenon? What causes these declines? What are the consequences of such declines for ecosystem functioning, plant and pollinator genetic heterogeneity, as well as for the economics of food and natural resource productivity? If adequate answers to these questions are unavailable, what are the reasons for the gaps in current knowledge? This will not be an exhaustive review but will provide adequate referencing so that these issues can be followed up further.

Pollinator Declines: Are They A Real Phenomenon?

Over the last few decades the perception has been growing among pollination biologists that pollinators have declined in numbers resulting in decreased seed and fruit set in

the plants that they service (Buchmann and Nabhan 1996, Allen-Wardell *et al.* 1998). However, a distinction needs to be made between declines of commercially raised pollinators of crop plants and those of natural pollinators. Globally, over 180 species of birds and mammals in 100 genera of vertebrate pollinators are already listed as endangered (Nabhan and Buchmann 1997). In Costa Rica, wild bee species richness in degraded forest lands declined from 70 to 37 species in 14 years (Nabhan and Buchmann 1997).

Despite the alarming trend of declines in fruit set of many commercial crops and naturally-growing plants, it is necessary to examine whether this decline is due to pollinator declines, whether these declines are of natural or commercially introduced pollinators, and therefore whether decreased fruit set can be automatically taken to be a surrogate for declining pollinator populations. There appears to be ample evidence of declines of commercial raised pollinators introduced into agroecosystems for pollination. However, the data are few for natural pollinators. In India, commercial honeybees are also suffering serious declines (Sihag 2001). Cox et al (1991) found that over-hunting of the megachiropteran fruit bats in the islands of the South Pacific reduced the fruit yields of some traditional harvests. Yet, several long-term studies, particularly of bees, have indicated that there is tremendous natural spatiotemporal unruliness in pollinator numbers (Cane and Tepedino 2001); this natural stochasticity (Roubik 2001, Williams et al. 2001) could confound very real trends of pollinator declines. Additionally, the pollinating organisms are also poorly known, which further impedes any examination of population trends. For example, Kearns (2001) believes that although flies are extremely important pollinators, this is not widely appreciated and consequently dipteran populations are not being adequately monitored. A consensus seems to be emerging that although there are definite indications that natural pollinators have declined worldwide, consistent, innovative, and appropriate sampling must be conducted to track these trends.

Pollinator Declines: Causes

Pesticides: Widespread usage of pesticides is a major threat to pollinators worldwide, especially with the onset of modern large-scale agricultural practices. This results in the requirement of large number of commercial bee colonies for pollination. These pollinators feed on the contaminated flowers, which has resulted in bee poisoning becoming the most important problem for beekeepers throughout the world (Johansen 1977). Honeybees are susceptible to almost all pesticides used commercially to control pests and diseases (Logan and Schofield 1984). Poisoned bees not only die but, even on exposure to sublethal doses, suffer disruption in dance behaviour and thereby breakdown of accurate communication of information about resources (Schricker and Stephen 1970). Poisoned queens are unable to maintain control over the hive and are often superceded (Chaudhry and Johansen 1971). A major factor contributing to the surface contact action of pesticides on pollinators such as bees is that their branched body hairs, which are adapted for picking up pollen, facilitate

enhanced surface loading of insecticides (Pradhan 1949). In India, also, pesticides cause severe mortality of bees (Anita et al. 1993). Although data are not yet available, application of pesticides in tea and coffee plantations in the diverse and ecologically sensitive areas of the Western Ghats can be severely damaging to natural pollinators. The effect of biological pesticides, e.g. genetically engineered plants carrying the Bt-corn toxin gene, on pollinators such as butterflies could be serious. For example Bt-corn plants might represent a risk because most hybrids express the Bt-toxin in pollen, and corn pollen is dispersed over at least 60 m by wind. Corn pollen deposited on other plants near cornfields can be ingested by the non-target organisms that consume these plants. Losey et al. (1999) found that larvae of the monarch butterfly, *Danaus plexippus*, reared on milkweed leaves dusted with pollen from Bt-corn, ate less, grew more slowly and suffered higher mortality than larvae reared on leaves dusted with untransformed corn pollen or on leaves without pollen.

Agricultural practices: Modern agriculture is large-scale, usually monoculture, and often involves removing surrounding natural vegetation. Monocultures reduce floral diversity, thus limiting the variety of pollinators that could be supported (O'Toole 1993). Extensive cultivation with loss of intervening natural vegetation results in loss of nesting areas for pollinators such as bees, fewer larval host plants for pollinators such as butterflies as well as loss of diversity of microhabitats suitable for egg-laying and early development (Kearns *et al.* 1998). Removal of nectar and pollen-providing "weeds" within expanses of agricultural monocultures by the use of herbicides has major effects on pollinators especially honeybees (King 1961). Agricultural practices that require frequent tilling and irrigation also cause declines in soil nesting bees. In India, the soil nesting bees *Andrena ilerda* and *A. laena* that are important pollinators of the oilseeds, *Brassica campestris* and *B. juncea*, showed six and thirteen-fold declines from 1980 to 1992 (Sihag 1993).

Fragmentation: In order to assess the effect of fragmentation on pollinator populations, it is necessary to know the scale that is relevant to the pollinator (Cane 2001, Borges 2002). For example, a landscape suitable for pollinating bees must contain nesting areas, nectar and pollen sources, that for pollinating butterflies should contain larval and adult food plants, while that for pollinating birds should contain abundant nectar resources. A landscape mosaic that contains these elements in the appropriate configuration that takes the mobility of pollinators into consideration would be able to sustain viable pollinator populations. There are very few data on the effect of fragmentation on pollinator populations, and these mostly pertain to the possible effect of fragmentation on the nesting attributes of bees (Aizen and Feinsinger 1994, Cane 2001). Powell and Powell (1987) found that male euglossine bees that are important pollinators of Neotropical orchids would not cross cleared areas larger than 100 m, thus indicating that the intervening matrix between forest fragments has a significant effect on pollinator movement and therefore also perhaps on pollinator populations. However, populations of understorey hummingbirds in Amazonia were found to be unaffected by fragmentation (Stouffer and Bierregaard 1995), thus

emphasizing the need to investigate fragmentation effects at scales relevant to different taxa.

Parasites: Infections by the parasitic mites *Varroa jacobsoni* and *Acarapsis woodi* have been devastating populations of commercial honeybees (Crane 1988, Ritter 1988). *Varroa*'s original host was the Asian honeybee *Apis cerana* from which it spread to *A. mellifera* when *mellifera* was introduced into Asia for beekeeping (Eickwort 1988). Problems of chemical resistance and large-scale population declines due to mite infestations have resulted in the general decline of beekeeping (Kearns *et al.* 1998). The Thai sac brood viral disease in Asian honeybees has also been damaging to commercial pollinations (Reddy *et al.* 1993, but see Rajagopal *et al.* 1998)

Non-native pollinators: The accidental release and now relentless spread of Africanized honeybees into the Americas is regarded as a major threat to commercial honeybees. Africanized honeybees are hybrids between European bees and the African subspecies *A. mellifera scutellata* (Rinderer 1988). Their aggressive nature, tendency to swarm when colonies are relatively small resulting in low honey production, hybridization with local honeybees resulting in transmission of the aggressive phenotype, and tendency to abandon areas under unfavorable environmental conditions makes them unsuitable for apiculture (Kearns *et al.* 1998). Analogous problems have been created by the bumblebee *Bombus terrestris* that was introduced into Japan to buzz-pollinate greenhouse tomatoes. Buzz-pollination is release of pollen from anthers by sonic waves produced by wing and thoracic muscle vibrations. This is necessary particularly in some families such as the Solanaceae whose flowers can only be serviced by pollinators who can effect these vibrations. Prior to the commercial use of bumblebees, hand-held vibrators were needed to effect pollination. The greenhouse bumblebees escaped and now are in competition with the native *Bombus*, as they usurp hives of the native bumblebees by killing the queens. *Bombus terrestris* is also causing problems in Israel, as it is in direct competition with the native bees in this region also (Dafni and Schmida 1996). Commercial honeybees when introduced into areas for crop pollination can also affect pollinator services provided by native pollinators. For example, various studies have recorded honeybees competing with pollinating birds, buprestid beetles, native meliponid and megachilid bees, with some megachilid bees even showing increased brood parasitism and reduced brood cell production in the presence of the honeybee (Kearns *et al.* 1998).

Pollinator Declines: Consequences for Pollinator Services

Plant population size, density and spatial isolation have complex interactions which can affect pollinator behaviour and thereby pollination (Kearns *et al.* 1998, Borges 2000, Somanathan and Borges 2000) above and beyond effects of plant floral display, pollinator reward structure, and plant breeding system, which have significant impacts on pollinator behaviour even in unfragmented landscapes (Waser 1983, Chittka and Thomson 2001).

Biological consequences: The reproductive output of plants in terms of fruit and seeds per fruit is determined by access to resources such as nutrients and water, as well as access to appropriate mates in the form of pollen. Access to appropriate mates is particularly important for plants that are obligately self-incompatible, and for those that occur in small populations and are subject to the negative effects of inbreeding and genetic drift (Saccheri *et al.* 1998, Packer and Owen 2001). In a study comprising 258 plant species, Burd (1994) found evidence of pollen limitation in 62% of the species, thus indicating that plants appear to be receiving less numbers of pollen than they can use for development into seeds. As mentioned earlier, although data on pollinator numbers are few, there are many studies that indicate pollination deficits (Kearns *et al.* 1998). The fundamental issue is, therefore, whether pollination deficits can be used as an effective surrogate for pollinator deficits in natural ecosystems (Thomson 2001). In agrecosystems, declining fruit or crop yield can often be directly linked to the lack of pollinator services. For example, application of the organophosphorous pesticide Fenitrothion caused severe decline of pollinators resulting in an annual harvest loss of 0.75 million kg of the blueberry crop in New Brunswick, Canada (Kevan and Phillips 2001). In this area, commercial production of blueberries depends on the pollination services of as many as 70 species of native insects (Kevan 1975). Another pesticide induced decline occurred in almond and honey production in California (Siebert 1980) which had to be ameliorated by the import of honeybees from Florida (Watanabe 1994).

Although several pollinators are generalists and visit several plant species, and although many plant species also receive services from a variety of pollinators, these services could be of variable quality. Thus certain pollinators cause greater fruit set in both natural and crop systems compared to others (Kumar and Gupta 1993). Some plant-pollinator systems, however, are obligate in that only one single pollinator services a single plant species. In such situations, loss of the pollinator would result in extinction of the plant (Washitani 1996, Borges 2000). If such plants are also keystone species, e.g. *Ficus*, then their extinction could result in cascading effects through communities of frugivores and other taxa dependent on the plants (Terborgh 1986). Some pollinators that are not exclusive to certain plants but service a variety of taxa could, if highly mobile, serve as important mobile links that connect plant communities, e.g. migratory butterflies and bats (Gilbert 1980).

Economic consequences: Various attempts have been made to evaluate the economic consequences of pollinator services and thereby of pollinator declines. For example, the economic value of a single wild bee serving as a pollinator of blueberry (*Vaccinium ashei*) was estimated at $20/- (Cane 1996). Kevan (1997) found that providing one hive of honeybees per hectare of apple orchards caused an increase in returns equivalent to 700% of the cost of pollination services. The value to US crop yields of pollinators other than honeybees may be as high as $6.7 billion per annum (Nabhan and Buchmann 1997).

Pollinator Declines: Knowledge Gaps And Amelioration

Adequate sampling of pollinator populations: Whether the spatiotemporal stochasticity of insect pollinator populations alluded to earlier is a real phenomenon or whether natural populations of pollinators are actually showing a declining trend can only be determined by consistent monitoring (Roubik 2001). Although large scale destructive sampling for insects, e.g. using light traps, may have been acceptable in the past, they are unacceptable today, since the sampling protocols themselves may deplete already endangered pollinator populations. Hence, non-destructive protocols need to be evolved, not just for insects, but for the entire set of invertebrate and vertebrate pollinators. In many cases, as mentioned earlier for flies, the importance of particular taxa as pollinators is completely unknown. Hence data need to be collected on pollinator services and on pollinator populations. Although evaluation of pollinator services for individual plant species requires experiments that consist of comparing fruit set in the presence and absence of the pollinator, even a record of visitors to the flowers of different species could help at a preliminary level to determine pollinator importance. Identification of important pollinators or guilds of pollinators can then serve to prioritise conservation efforts.

Effects of pesticides and appropriate laboratory trials: Although the toxic effects of pesticides on many commercial pollinators, e.g. honeybees, is known, their effects on wild pollinators is largely unrecorded. Since many pesticides are picked up on the body surface and surface to volume ratios are involved, smaller bees may be more susceptible than larger bees; however more research is needed. Considerable research is required on a) natural control methods and pesticides that are not lethal to pollinators, and b) protocols of pesticide application that minimize exposure and thereby lethal effects on pollinators. For example, pesticide application could be scheduled either when pollinators are least active during the day, or before and after flowering. Data are needed on crop yields using natural control methods. For example, some studies indicate that organic farming that encourages and maintains natural habitat, which in turn sustains natural populations of pest predators, is as economically viable as farming with pesticides (Batra 1981). More data are needed on this issue. In the current globalization scenario, unless consumers are convinced of overall benefits to human and ecosystem health of consuming products free of pesticides, and unless organic farming is shown to be as economically viable as that using pesticides when all externalities such as pesticide induced death and/or disease are factored in, there is always the danger that producers that use pesticides will be able to dictate prices (Kevan 2001).

Pollinator behaviour and ecology: Knowledge of pollinators is heavily biased toward bees, and that too heavily towards the Neotropical, North American and European fauna. For example, a major treatise on tropical bees (Roubik 1989) cites 1400 references but only 89 of these refer specifically to south and southeast Asia.

Pollinators such as butterflies, beetles, flies, thrips, birds and mammals have been severely neglected. Commercial honeybees alone, even if bred intensively, cannot provide pollinator services in all ecosystems. As has been seen, even in most agroecosystems, the contribution to pollinator services by native pollinators is significant. Therefore data on natural pollinator ecology, especially feeding and breeding biology, is vital to maintain the integrity of both natural and agroecosystems, as is an understanding of the complexity of the mutualisms involved.

Better economic evaluations: From a pragmatic perspective, the more knowledge we have about the economic value of pollinators and their costs of replacement, the more convinced will the general public be about the value of pollinators. It is apparent that the pollinator crisis in the USA especially in agroecosystems has become sufficiently alarming for the former US Secretary of the Interior, Bruce Babbitt, to say the following in a public speech in 1998: "Pollinators: These hardworking heroes of nature are not well understood but clearly in peril.....Loss of habitat, poisonings, and fragmentation of plant life on which they depend is reducing the number of pollinators alarmingly". Jamie Rapport Clark in a 1999 Director's memo to all US Fish and Wildlife Service biologists said: "I am convinced that restoring and conserving pollinators will be one of the most pressing challenges to maintaining biodiversity and healthy ecosystems in the coming decades." It is only if the pollinator crisis can be seen to have a direct current or future impact on the economy or on public perceptions of planetary health, will politicians be forced to institute policy to meet the demands of this crisis effectively. Scientists and economists must work together urgently towards this goal.

Looking at the future of pollination services in India

The pollinators of the Indian flora are very poorly studied, except for some economically valuable plants, e.g. cardamom. Visitors and thereby putative pollinators of the natural shrub and tree flora have been recorded for only a few Indian forests, e.g. evergreen rain forest in Kakachi (Devy Davidar 2003), semi-evergreen crest forest in Bhimashankar (Somanathan and Borges 2000, Somanathan and Borges 2001), and a mangrove forest along the eastern coast (Pandit and Choudhury 2001). The vast remainder of sites and plants remain unstudied and do not feature in a pollination database. This scenario must change if practical conservation measures and effective protection to pollinators and plants is to be effected. Although there is extensive commercial exploitation of fruit crops of forest trees such as *Garcinia gummi-gutta* and *Myristica* spp, there is no knowledge of the pollination of these species, which is an upstream process that must be necessarily conserved to ensure continued fruit production on existing trees. The trend of conversion of coffee plantations to tea gardens following the fall in coffee prices (Ajith Kumar; personal communication) could have very serious consequences for the natural pollinator fauna of Indian forests. This is because most shade coffee plantations retain original old-growth shade trees. Removal and replacement of such trees by exotics such as *Grevillea robusta*, as occurs in tea

gardens, would impact on pollinator fauna many of whom could be using these tree species for larval and adult food resources, mating and nesting spaces and other purposes. Furthermore, considering that most of the southern Indian hills are largely a mosaic of tea and coffee plantations, with natural forest fragments occupying a very small area of this composite matrix, the seriousness of land use changes cannot be ignored. Despite the alarming trends worldwide about the effect of crop pesticides on native and commercial pollinators, the agricultural sector in India is still heavily dependent on pesticides that are harmful to pollinators such as honeybees (e.g. Reddy and Reddy 2002). Although there is a requirement of 150 million honeybee colonies in India for the successful pollination of commercial crops, only 0.004 percent of this requirement was met in 1982 after which the numbers declined still further due to disease (Sihag 2001). The "All India Coordinated Project on Honeybee Research and Training", set up by the Indian Council of Agricultural Research to facilitate cross-pollination of crop plants and honey production, has largely been a failure (Sihag 2001). The genuine shortage of competent systematists to identify pollinator taxa is also a major constraint in the conservation and study of species interactions. Policy makers must pay serious attention to this shortage and must encourage the growth of scientific systematics and pollinator conservation in the country.

Pollinator services are complex, and with as yet unknown properties of resilience or sensitivity to perturbations. It is very likely that the pace of habitat degradation will proceed at a rate faster than our understanding of this complexity. In this scenario of only slowly diminishing ignorance (Borges 2003), the best strategy would perhaps be to devise pragmatic, low-risk strategies for the maintenance of pollinator diversity. Such pragmatic strategies might involve the assiduous protection of the maximum number of refugia containing natural vegetation whether these occur around the edges of agricultural lands, or as forest islands within a sea of plantations or other such matrix. Such preservative strategies coupled with active interaction of policy makers, economists and biologists appears to be the only method for the successful maintenance of pollinator diversity.

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Chapter 17

SOIL FAUNA STUDIES IN THE RAINFORESTS OF NORTHEAST INDIA: KNOWLEDGE GAPS AND AREAS OF RESEARCH PRIORITIES

V.T. Darlong, S.J.S. Hattar and J.R.B. Alfred

Introduction

General introduction

The soil fauna represents one of the most complex, and yet rewarding areas of current biological exploration. It perhaps remains one of the least known biological frontiers, particularly in terms of soil zoological systematics and taxonomy. The diversity of animals that inhabit the different soil types is so complex that most of the currently known *'difficult taxonomic groups'* continue to be those living in the soils.

The life beneath us is indeed a spectacular assemblage of both plant and animal communities. Soil biologists call these communities as 'soil organisms', while soil zoologists call them as 'soil animals' or 'soil fauna'. Thus, according to soil biologists, there are three categories of organisms, viz., (a) *microbiota* (soil algae, bacteria, fungi and protozoa), (b) *mesobiota* (nematodes, microarthropods) and (c) *macrobiota* (larger arthropods, molluscs, earthworms). The soil zoologists however prefer to categorize them into (a) *microflora* (bacteria, actinomycetes, fungi, algae); (b) *microfauna* (protozoans); (c) *mesofauna* (rotifers, acarina, collembola, protura); (d) *macrofauna* (larger arthropods, molluscs, spiders); (e) *megafauna* (earthworms). The soil fauna may also be referred to as *endopedonic,* i.e. those that live inside the soil body and *exopedonic,* i.e. those that live outside the soil body.

All groups of animals are represented in the soil (except Coelenterata and Echinodermata). Even within a small area, the species diversity is remarkable. However, the arthropods constitute the greatest diversity of soil inhabiting species, and Acarina and Collembola represent the bulk of arthropod group. Other less abundant groups are Symphyta, Pauropoda, Protura, Diplura, Hymenoptera, Chilopoda, Diplopoda, Coleoptera, Aracneida, Isopoda, Isoptera, Psocoptera, Dermaptera, Orthoptera, Diptera, Pesudoscorpionida, etc. Besides these, the nematoda, annelida, molluscs or gastropoda, rotifera, protozoa, etc. are abundantly present in most soil types. Many vertebrates also spend part of their life in the Soil-

Ecological significance of soil fauna

The animals in the soil participate in numerous processes of soil formation and affect the usefulness of soils. The classical role of the soil fauna is in the breakdown of dead plants and animals, which are returned to the soil. Accompanying this decaying process is the release of nutrients from the organic body of plants and animals into the soil. Effects of animals in and on soil results in changes in soil fabrics, i.e., the size, shape, arrangement of soil components and changes in soil composition.

There are at least twelve kinds of activities by which soil animals affect the soil (Hole, 1981). These activities include mounding, mixing, forming voids, back-filling voids, forming and destroying peds, regulating soil erosion, regulating movement of water and air in soil, regulating plant litter, regulating animal litter, regulating nutrient cycling, regulating biota, and producing special constituents through the processes of

regurgitation, mixing of saliva or excreta with soil materials.

Since the animals in the soil participate significantly in the processes of soil formation, function and maintenance, the soil fauna also serve as sensitive indicators of the states of soils and of the impacts of environmental changes. The biomass of fauna is a relatively small proportion of the total soil mass, particularly in a mineral soil, yet the activity of these animals is important in moving material upward against the forces of gravity and of the flow of fluids, in altering soil fabric and micro-topography, in changing distribution patterns of soil materials and plant nutrients and in relating processes and assemblages of materials and organisms.

Importance of soil zoology in the context of present day intensive agriculture, forestry and conservation practices

Land is a finite resource. Both agriculture and forestry practices demand land for expansion and sustainable growth. Since additional land under agriculture is difficult, there is an urgent need to sustain soil health. The soil fauna and microbes reduce the carbonaceous residues of dead organism or their parts to the inorganic state. The organic matter decomposition and humus formation in soil is of great relevance to agriculture as it benefits crop growth.

On the other hand, many soil organisms, particularly in their larval stages, such as the white grubs, insects, mites, nematodes, snails and slugs, and the soil-inhabiting rodents are serious pests to agricultural crops, it is important that these organisms are studied in detail for systematic actions, such as collection and destroying of adults, lopping of trees where they aggregate, and to undertake biological, cultural and chemical control.

On the other hand in the promotion of sustainable forestry practices and healthy protected or conservation areas, many of the insects and beetles, which act as pollinators (as also defoliators, wood borers, etc), spend their larval stages in the soil and on the litter. These complex biological functions and dynamism must be maintained and better understood in order to promote sustainable forestry practices.

Objectives of the present study

The present paper is to briefly present an overview of soil fauna studies from northeast India, identify knowledge gaps and suggest areas of research priorities in this field of studies. It is also to focus the ecological significance of soil fauna in the ecosystem functions and dynamism in agriculture, forestry and protected areas so that the discipline could attract more of Indian biologists to pursue serious research. For reasons of simplicity in this paper, the entire northeast has been considered as 'rainforests', although there are ecological variations within the region, between the forest types, altitudes and so on.

Brief Review Of Research On Soil Fauna

Brief history and growth of soil fauna studies

Studies on soil fauna had received inadequate attention from pedologists for a long time, despite early works by White (1789) and Darwin (1840, 1881) on the earthworms and other invertebrate soil fauna, evaluating their role in humus formation. Thereafter, the vast majority of scientific literature on soil fauna, both taxonomy and ecology, have been mostly from the European and North American soils. Yet soil zoology truly developed as a discrete discipline only during the last 50-60 years. Landmarks in this maturation process included the appearance of Kuhnelt's (1961) *Bodenbiologie*, produced in an English edition in 1961, summarizing the greater part of what was known about soil animals, and Franz's (1950) *Bodenzoologie*, in which he emphasized the practical implications of the study of the soil fauna.

These works heralded, a rapid spawning of concurrent literature on soil fauna and international symposia, devoted exclusively to soil animals. Some of these important works included those of Kevan (1955, 1962), Farb (1959), Macfadyen (1957), Doeksen & Drift (1963), Burges & Raw (1967), Graff & Satchell (1967), Vanek (1975), Wallwork (1976), and Lebrun *et. al.* (1983). These authors have drawn together a considerable amount of information on the general biology and ecology of soil animals, and have done much to stimulate interest in this field. Also symptomatic of this interest was the creation of international journals of soil biology and ecology, viz. *Pedobiologia* in 1961 and *Revue D'Ecologie et de Biologic du Sol* in 1964.

The rapid accumulation of literature on soil fauna during this period was also due to simultaneous availability of improved soil fauna sampling techniques, largely due to the works of Macfadyen (1953, 1955, 1961) and Alexander & Jackson (1955), though most were improvements and modifications of Tullgren's apparatus.

With the inception of the International Biological Programme in 1964, which aimed at "world study of biological productivity and human adaptability", soil ecology studies had been sponsored by the section on terrestrial productivity. The result of this programme was the birth of an IBP Handbook (Phillipson, 1971), which described methods for biological research in soil ecology. This was also indicative of the beginning of quantitative approach to soil faunal studies with special reference to productivity and energy flow, which is now a major thrust area of many soil faunal investigations in different parts of the world.

Since the tropical soils of the world constitute a critical and fragile ecosystem, in the 1990s UNESCO sponsored a decade long programme on "Tropical Soil Biology and Fertility", resulted in the development of a series of scientific literature on tropical soils, including the soil zoology. Today, soil zoology has become a well-organized international scientific discipline. Since 1955, the study is regularly supplemented and enriched through periodic international colloquium on soil zoology. The proceedings of these symposia are regularly brought out and these have become a major factor in

promoting research and international collaboration in soil biology and ecology.

Soil fauna studies in India

Systematic survey of literature on Indian soil zoology is difficult as they are distributed in obscure journals. Scanty literature on the subject speaks of its poor attention received from Indian pedologists. Singh (1978) has reviewed soil fauna studies in India. Added to this, there is growing evidence of interest from Indian workers as indicated by the proceedings of two national symposia "Soil *Biology and Ecology in India"* (Edwards & Veeresh, 1978) and *"Progress in* Soil *Biology and Ecology in India"* (Veeresh, 1981), followed by *"Applied Soil Biology and Ecology"* (Veeresh & Rajagopal, 1983) and *"Advances in Management and Conservation of Soil Fauna"* (Veeresh *et. al* . 1991), signaling the gradual maturity of soil faunal studies in India. These publications attempted to bridge the gap in the knowledge on soil biology and ecology in this country, which is, as yet insignificant compared to her vast landscape variation and severe pressures on fragile soils. Added to this venture was the launching of the *Indian Journal of Soil Biology and Ecology* in 1981.

The earliest taxonomic records of soil fauna from the Indian sub-continent dates back to Pocock (1892), reporting upon the ground-dwelling myriapods of the then Ceylon (Sri Lanka) and Southern India. Writing on the then British India, Bingham (1903) reported on many of the ground-dwelling ants, while Imms (1912) described new collembolan species of this sub-continent.

Qualitative and quantitative studies of soil fauna, particularly the micro-arthropods from Indian soils began from the mid-sixties, although ecological studies were initiated much earlier (Trehan, 1945). However, major contributions have been from the agricultural fields, grasslands, abandoned fields and tea gardens, and very few from tropical rainforests. While the microarthropod studies from various forest floors included those of Banerjee (1972), Hazra (1978), Annadurai *et. al.* (1988), Reddy & Reddy (1996), Bisht & Chattoraj (1998) etc. Sanyal (1995) has reviewed the ecological studies of soil oribatid mites in India. And reports from tropical forest soil and litter microarthropods are limited to the works of Singh & Singh (1975), Prabhoo (1976), and Hazra (1982). Most of the recent literatures on Indian soil fauna are again from the agricultural fields.

Soil fauna studies from Northeast India

Fragmentary knowledge of the soil fauna of northeast India is through the limited reports by Reddy (1980, 1981), Reddy & Alfred (1978a,b), Hattar & Alfred (1984) and Paul & Alfred (1984, 1995) concentrating on the arthropod populations of the pine forest floors and adjoining cultivated lands at higher elevations of Meghalaya; Vatsauliya & Alfred (1980) and Vatsauliya (1981) reporting on the soil fauna of jhum fallows at lower elevations; Darlong & Alfred (1982, 1986, 1989), Alfred *et al.* (1991), Hattar et al. (1992, 1998) and Reddy & Ao (1995) showing the differences in the arthropod structure in the forests and jhum fallows and other cultivated fields of this region. Chakraborti &

Bhattacharya (1996) studied microarthropods of rubber cultivations in Tripura.

Soil oribatid mites from Tripura have been well studied by Sarkar (1983, 1985, 1986, 1990,1991,1992), Sarkar & Subias (1984), Subias & Sarkar (1984), and Cancela da Fonseca & Sarkar (1996, 1998). Sanyal (1995) described the oribatid mites of Meghalaya. Taxonomic studies on Collembola from the region are those of Carpenter (1917, 1924), Mitra (1976), Mari Mutt & Bhattacharjee (1980), Bhattacharjee (1984, 1985) and Hazra (1995). In addition, earthworms had been studied by Reddy & Alfred (1978b), Mishra & Ramakrishnan (1988), Darlong & Alfred (1991) and Reddy & Ao (1995) from this region.

These studies from northeast India have been supplemented and enriched through a number of doctoral theses from the region notably those of Reddy (1980), Vatsauliya (1981), Darlong (1984), Bhadauria (1987), Ao (1987), and Paul (1992), all from the North Eastern Hill University, and Sarkar (1981) from Tripura under the then Calcutta University. However, current research on soil fauna are limited in the region in that taxonomic works are being earned out by the Zoological Survey of India, and the ecological studies by the Forestry Department of Mizoram University and the Life Science Department of Manipur University.

Knowledge Gaps, Research Priorities, Future Of Soil Zoology Systematics And Biodiversity Research

Knowledge gaps and research priorities

Stabilization of extraction methodology

A major constraint in the studies of soil fauna from the tropical soils of northeast India is the lack of stabilization of extraction procedures and methodology. Both ecological and taxonomic studies on soil fauna require efficient extraction apparatus. Given the diversity of habitats, different life cycle stages (mobile to immobile or large size to microscopic), sample size needs and time gap between collection and extraction, it is necessary to standardize the collection procedures and to test the extraction efficiencies of the apparatus used considering all these parameters.

Research priorities

There are ranges of research priorities, both academic and applied, which can be identified for the tropical rainforests of northeast India, as follows:

(a) There is the need to know more about what and how many species of animals inhabit the tropical soils, either wholly or partially, including the burrowing animals and their ecological impact on the overall soil dynamics in tropical rainforests.

(b) Soil faunal taxonomy is laborious, time consuming, and challenging. There is the need to create professionally rewarding avenues to attract young talented soil zoology taxonomists across the Indian universities and research institutes.

(c) There is the need to generate data on sociology of soil fauna, such as, (i) which species are likely to occur together and on which kinds of habitats, (ii) what fraction of beetles (or other) fauna, particularly those specialized as pollinators, on a given tropical tree species of a rainforest is effectively specialized to do it without spending part of its life stages on or in the soil?

(d) Research is needed at the individual organisms or species within the communities to know ecological physiology of the individual, life history strategies, etc.

(e) Research is also needed at the populations of individual soil faunal species or groups within the overall soil faunal Communities. The ability of populations to increase needs to be understood so that effects of controlling mechanisms can be quantified. For example, just how effectively predators exploit prey populations?

(f) Research is needed at the community of soil fauna itself to understand the organization of the community and the dynamics of the community (for example, how quickly or at what rate leaf litter of different plant species on tropical rainforest floor mineralises through combine participation of leaf foragers, consumers and decomposers?).

(g) We need to know more about what constitutes or determines "sustainable" soil health" in the tropics? For example, (a) Is it the types of organisms present in the soil or their ratio of numbers (such as bacteria, fungi, actinomycetes, arthropods, insects, annelids, nematodes, arachnids, mollusks or vertebrates), (b) Is it the way how each of these organisms contribute to the physical properties of the soil, humus formation, soil aeration, mineralization, etc.? (c) What then happens with the changing environment of tropical landscapes such as shifting cultivation?

(h) What is the significance of soil inhabiting vertebrates in the tropical rainforests of northeast India, such as relationships between bamboo flowerings and increase in rodent population?

(i) There is very little knowledge and documentation on the pest nature and beneficial aspects of soil fauna from the agricultural lands and forests of northeast India.

Future of soil zoology and biodiversity research

Soil fauna: the last biotic frontier?

Many modem soil biologists consider the soil fauna to be the last biotic frontier by their sheer numbers, diversity of species, difficult taxonomic compositions and numbers of undescribed species (Andre *et al.*, 1994). Soil biodiversity is perhaps one area that has yet remained least explored scientifically. Different approaches to global biodiversity estimates vary between as small as 3 million to as large as 80 million species. However, a recent short survey by a team of soil biologists of micro-arthropods from coastal sand dunes (characterized by very low organic content and extreme dryness) by using an efficient new floatation technique yielded as much as 1,75,000-14,00,000

individuals per sq m. The soil biologists further argued that if all the possible microflora (bacteria, fungi, actinomycetes, etc.) and microfauna (bacteria, protozoa, nematodes, enchytraeids, etc.) are possible to be identified and truly accounted in the debate on biodiversity, then perhaps no other ecosystem like the soil can match on its richness of biodiversity. Thus, the soil is considered to constitute a huge reservoir for biodiversity, a challenge for further research on biodiversity.

Soil fauna in the National Biodiversity Strategy and Action Plan

The National Biodiversity Strategy and Action Plan (NBSAP) is a guideline preparation of strategies and action plans for protection, promotion and conservation of national biodiversity wealth. However, in the thematic notes, the soil fauna as a distinct discipline does not find any mention in the scheme of NBSAP, although micro-organism diversity (bacteria, fungi, virus, actinomycetes and protozoans) have been mentioned. Knowing the values and significance of the soil organisms as mentioned above, it is indeed necessary that the soil fauna must find a place in the NBSAP. It is probable that many of these organisms are perhaps lost forever much before they could be described by science.

Systematic soil biologists and the biodiversity challenge

One of the foremost challenges faced by conservation biologists in general and systematic biologists in particular is completing the inventory of the world's biodiversity and its various components before they are lost forever. Of course, the greatest challenge obviously comes from the systematic soil biologists for correct identification of soil fauna of different ecosystems of the world, particularly from the tropical and sub tropical world. The task ahead is enormous and systematic biologists have to plan pivotal role in executing the process of biodiversity inventory and monitoring.

The overriding importance of systematic particularly in the study of soil zoology and its creative role in fulfilling the emerging needs of science and society has never been realized so greatly as it is today. The fundamental and all-embracing nature of systematic will become far more evident by its increased use and application in almost every field of biology and biodiversity research. Systematic studies are becoming increasingly relevant not only in soil zoology, but also in most priority areas of biology such as biodiversity inventory, monitoring, mapping, prospecting, ethnobiology, conservation biology, biomodelling, bioinformatics, environmental impact assessment and so on.

Role of taxonomy in ecological and applied research

Adequate taxonomic foundation is needed on which ecologists can work, and more particularly good identification is needed in studying various aspects of the soil fauna, such as, community dynamics, indicator species, diversity indices, description of under-researched ecosystems, little known-groups of unknown ecological significance, ecological variation within species, nature conservation or biosphere reserves,

environmental impact assessment of developmental projects, amenity species, etc. However, in trying to understand all these aspects, the soil ecologists may often ask the following questions:

(a) Must all the species covered be identified, or can *the* essential ecological answers be obtained by more selective methods?

(b) How quickly and completely is the ecologist likely to master the taxonomy of the organisms within his project?

(c) To what extents can the need for identification be by-passed using measures of ecosystems based on biomass, and are these an effective substitute?

(d) What risk of error is incurred by concentrating on studies of, for example, biological production on common and easily identified species, or those with high biomass, such as earthworms?

The soil faunal studies in general, continue to be difficult taxonomic groups to most soil ecologists due to various reasons, including (a) Excessive numbers of species, (b) Large numbers of undescribed taxa, (c) Large numbers of individuals, (d) Difficult life histories, (e) Insufficient basis for classification, (f) Infra-specific variations, (g) Limited specialists of few groups, or lack of specialists for most groups, (h) Limited or lack of referral centers for identification, and so on.

Conclusions

Soil zoology today continues to be one of the least known or explored biological frontiers. Most of our present day *'difficult taxonomic groups'* continue to be those organisms living in the soil. In Indian context, we do not know as yet precisely what and how many species of animals inhabit our soils under different ecosystems and land use patterns, nor do we know much about the impact of various land uses and agro-horti-silvicultural practices on the animals inhabiting the soil.

Taking into account their ecological importance, biodiversity values and extent of present taxonomic difficulties, soil zoology requires greater patronage and attention from diverse discipline of biology. There is urgent need to develop identification keys, handbooks, and monographs on different groups of soil fauna from this region in particular. Simultaneously there is the need to train more specialists in different groups of soil fauna from this region.

There is also urgent need to make the science of systematics and taxonomy to be more rewarding discipline than what it is today). In this context, together with Pushpangadan & Nair (2001) we may ask the following questions in order to make the science of systematics and taxonomy, particularly soil faunal systematics to be more rewarding

a. Why do systematic biologists fail to take the science of systematic to the forefront as 'crisis management discipline', especially in view of the gigantic task of completing biological inventories of major biomes in the world, particularly tropical forest floors and soils?

b. Why do governments/institutions fail to adequately support systematic biology research, both classical and modern (chemo-systematic, cyto-taxonomy, molecular systematic) through adequate capacity building processes and infrastructure development?

c. Why does systematic, particularly soil zoology systematic, fail to attract universities and young talented researchers at a time when the world requires more trained taxonomists to fulfill the mandates of inventorying and monitoring biodiversity resources?

d. What is the functional status and present profile of the premier taxonomic research centers in the world, particularly in the biodiversity rich tropical developing countries, including India?

e. How do systematic biologists propose to respond to the ongoing decline or neglect of systematic and what strategies are they planning to revive the practice of systematic thereby providing new dimensions to the present 'hot-spots' of biodiversity research?

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Chapter 18

BIODIVERSITY AND WILDLIFE RESEARCH IN NORTHEAST INDIA: NEW INITIATIVES BY THE WILDLIFE INSTITUTE OF INDIA

A. K. Gupta

- Introduction
- Wildlife Research Projects
- New Initiatives
- References

Introduction

The northeast India, being at the confluence of three major bio-geographical realm of the world, is extremely rich in floral and faunal biodiversity with several endemic species. Northeast, with seven states (Arunachal Pradesh, Assam, Manipur, Nagaland, Meghalaya, Mizoram, and Tripura), represents one of the few hot spots of biodiversity of the world. All the northeastern states make up for about 8% of the total geographical area of the country, but has about 25% of the country's total forest areas supporting about 30% of the total growing stock of the forest of the country. Nearly 64% of the total geographical area of northeast (2,55,000 km^2) is having forest cover, of which only 35% of forest are under the control of Government and rest 65% are under the control of District Council, Village Communities and Private Ownership. About 70% of the total geographical area is mountainous and hilly and rest 30% is under Brahmaputra and Barak valley systems. The entire region is highly populated with about two third of total human population [31.5 million (1991 census)] is in Assam and remaining in other 6 states. The human population density is ca. 250 persons/ km^2 in Tripura and Assam, less than 100 persons /km^2 in Mizoram, Manipur, Nagaland, Meghalaya, and about 10 persons/km^2 in Arunachal Pradesh. The demographic feature of northeastern states is unique in that there are more than 100 recognized tribes, which inhabit mostly the hill areas and each with distinct culture, ethos, and traditional knowledge systems. The majority of the people survive on subsistence economy based mainly on the agriculture, supplemented with limited horticulture, animal husbandry, crafts/handloom, etc. The forestry and wildlife resources contribute substantially in meeting even the needs of subsistence economy, which make the dependency of the people on the forestry resources very high. The use of areas rich in forestry and wildlife resources (mainly of practicing shifting cultivation across the region) and extraction of various forest products from the forests is in vogue since long past as an accepted practice. One unique feature of this natural-resource-dependent economy is its close and intimate linkages with the social, cultural, and traditional institutions and life-style of various communities. This linkage between the life-style and extraction and utilization of natural resources, which was in total harmony till the carrying capacity of the natural resources was sufficient to cater to the burgeoning needs of the people, has now over the past few decades totally disturbed following fast degeneration of the natural resources on the one hand and multiple increase in the user groups. Another major conservation problem is the inter-state border disputes and presence of a long and porous international boundary, which also facilitate draining down of natural forestry and wildlife resources across the border, thus further depriving the states with their natural wealth. A small contribution to this is also from the present civil unrest problem in the state, which is quite adversely affecting the management of protected areas as well as other forests under the management and control of the Government.

Northeast India is one of the rainiest regions of the world being fed with two monsoons. The highest rainfall area is also present in this region, the town called Mawsynram,

about 10 km away from earlier highest rainfall area (Chirapunjee) in the state of Meghalaya (the abode of clouds and also called as Scotland of India). The tropical climate of the regions with high rain fall and plenty of sun-light coupled with unique bio-geographical positioning of this region is responsible for rich biodiversity in terms of floral and faunal elements (Table 1). Recognizing the importance of this region as one of the hot spots, majority of the biodiversity rich areas of the region has been placed inside the protected area network system comprising mainly of the National Parks and Sanctuary. However, the total area under the protected area network is only about 6.5%, which ideally should be around 10% as per the policy of the government. The details on the forest area, forest cover and area under protected areas for each of eight states is presented in Table 2 (also refer Fig. 1).

Table 1: Biodiversity in Northeast India (Ghosh & Tiwari, 1984)

PLANT/ ANIMAL GROUP	NO. OF SPECIES
Plants Flowering plants	7,500
Orchids	700
Bamboos	58
Citrus	64
Conifers	28
Mosses	500
Ferns	700
Lichen	728
Animals Buffer flies	183
Molluscs	50
Fishes	236
Amphibians	64
Reptiles	137
Birds	541
Mammalian	160

Table 2: Forest area, forest cover, and area under protected area network in northeastern states (Source: FSI, 2001)

	Arunachal Pradesh	Assam	Manipur	Mizoram	Nagaland	Meghalaya	Tripura	Sikkim
Total Area	83743	78438	22327	21081	16579	22429	10486	9096
Forest Area (%)	51540 (61.5)	30708 (39.2)	15154 (67.9)	15935 (75.6)	8629 (52.0)	9494 (42.3)	6292 (60.0)	2650 (37.3)
Forest Cover (%)	68.602 (81.9)	23824 (30.4)	17418 (78)	18775 (89.1)	14221 (85.8)	15567 (69.8)	5546 (52.9)	3129 (44.1)
Area under PAs (%)	9582.6 (11.4)	2113.5 (2.7)	224.8 (1.1)	884 (4.2)	326.4 (1.9)	301.7 (1.3)	603.6 (5.8)	2049.1 (22.5)
No.of WLS	10	13	1	4	3	3	4	5
Area under WLS (%)	7114.45 (8.5)	939.8 (1.2)	184.8 (0.83)	634 (3.0)	24.4 (0.1)	34.2 (0.15)	603.6 (5.8)	265.1 (3.7)
No.of NPs	2	3	1	2	1	2	-	1
Area under NP (%)	2468.23 (2.95)	1173.7 (1.5)	40 (0.18)	250 (1.2)	202 (1.2)	267.5 (1.2)	-	1784 (25.1)

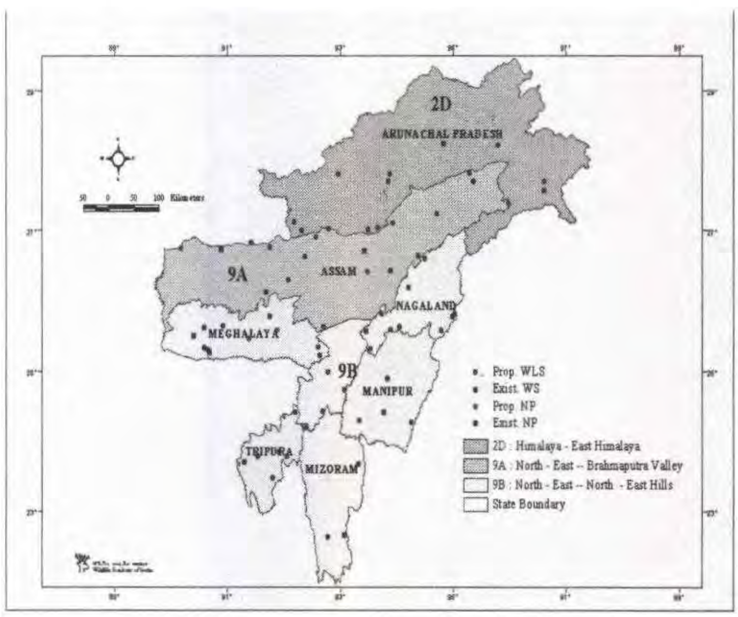

Fig. 1 The Protected Area network in northeast India

Besides the above protected areas, there are 8 Elephant Reserves (Sonitpur, Dibru, Kaziranga-Karbi and Manas in Assam; Kameng and Deomali in Arunachal Pradesh; Intaki in Nagaland; and South Garo Hills in Meghalaya)under the auspices of the Project Elephant Directorate and 6 Tiger Reserves (Dampa in Mizoram; Manas, Nameri, and Kaziranga in Assam; Namdapha and Pakki in Arunachal Pradesh) under the auspices of the Project Tiger Directorate of the Ministry of Environment and Forests, Government of India.

Wildlife Research Projects

Due to its uniqueness in various key elements affecting the biodiversity contained in different states of this region, the research projects also call for special measures to cater to those very specific needs that may differ in more than one ways from other wilderness areas of the country. The Wildlife Institute of India (WII) has been engaged for past many years in undertaking and collaborating with the concerned Stated Forest Department (SFDs) in facilitating both basic and applied project based research in various states of this region. The number of research projects in different protected areas undertaken on various species/issues by the WII is presented in Table 3 & 4, respectively.

Table 3: Number of various wildlife research projects undertaken by the WII in different protected areas

State	Number of Research Projects	Name of the Protected Area (no. of PAs covered/total number of PAs in the state)
Assam	11	Manas, Kaziranga, Pabitora, Borajan (4/18)
Tripura	6	Trishna, Sepahijala, Gumti (3/4)
Arunachal Pradesh	11	Pakhui, Namdapha, Mehao, Kamleng (4/13)
Meghalaya	5	Nongkhyllem, Siju, Balphakram, Nokrak(4/5)
Mizoram	4	Ngengpui (1/6)
Manipurl	2	Keibul-Lamjao (1/4)
Nagaland	1	Across state (0/4)
TOTAL	**40**	**17/54 (31.5%)**

Table 4: Major fauna covered under various research projects by the WII in northeastern states.

STATE	SPECIES
Assam	Buffalo, Crane, Pygmy hog, gibbon, hog deer=5
Tripura	Langurs(3), monkey (1), gibbon, gaur, hog deer = 7
Arunachal Pradesh	Clouded leopard, hog deer, Arboreal mammals, hornbill, takin, bat, pheasants = 7
Meghalaya	Elephant, clouded leopard, hog deer, gibbon = 4
Mizoram	Gibbon, hog deer = 2
Manipur	Brow antler deer (sangai), hog deer = 2
Nagaland	Hog deer = 1
Region	Floral survey, Birds survey, Turtle survey, Lesser carnivore
TOTAL	**16 Individual species**

As is evident from the above referred tables, only a small fraction of the total number of protected areas (31.5%) and individual wildlife species (16) has been covered in various research projects of the WII. Therefore, there exists ample scope to cover different biodiversity rich areas to study many a highly endangered and endemic species of flora and fauna. Besides the research projects based on individual species, few surveys have also been undertaken by the WII covering flora, birds, turtles and lesser carnivores. The WII has also undertaken few projects on different subject matters as a part of dissertation work for partial fulfillment of the post-graduate degree course in wildlife biology. Till date, the following topics have been covered:

- Shifting Cultivation and Conservation of Tropical Forest Bird Communities in Mizoram (94-95)
- Food selection and ranging in hoolock gibbon (*Hylobates hoolock*, Harlan 1834) in Borajan Reserved Forests, Assam.
- Effect of habitat alternation on herpetofauna assemblages of evergreen forest in Mizoram (97-99).

- Habitat use by Rhino and other associate ungulates in Kaziranga NP. Assam (99-01).
- Pattern in species composition and distribution among vascular epiphytes in low lying semi-evergreen forests of Arunachal Pradesh (99-01).

Some of the major research/dissertation projects undertaken by the WII in the northeaster states during the last two decades are listed as below (not an exhaustive list):

1. The Asiatic wild buffalo in the Assam State: Population genetics and ecology for its management
2. Development of an Indian Cooperative WL Health Programme
3. Crane survey
4. Impact assessment of Jorhat-Numaligarh Pipeline Project.
5. Ecological assessment of proposed Hydro treatment plant.
6. Genetic swapping of wild buffalo.
7. Disease survey in Kaziranga National Park.
8. Biology, ecology and conservation of Phayre's leaf monkey in Tripura.
9. Effect of shifting cultivation on the ecology and conservation of mammals with special reference to *Trachypithecus phayrei* in Northeast India.
10. Conservation ecology of an isolated population of gaur in Trishna Wildlife Sanctuary, Tripura.
11. A survey of the clouded leopard in North-east India.
12. Responses of arboreal mammals to selective logging in Arunachal Pradesh.
13. An ecological study of sympatric hornbills and fruiting patterns in a tropical forest in Arunachal Pradesh.
14. Birds survey in selected localities of Arunachal Pradesh.
15. An ecological study of sympatric hornbills and fruiting patterns in a tropical forest in Arunachal Pradesh.
16. Investigation of the bio-geographic patterns of relevance of planning of long terms wildlife conservation.
17. Status survey of elephants, their habits and an assessment of elephant – human conflict in Garo Hills.
18. A survey of the clouded leopard in North-East India.

19. Management of forests in India for biological diversity and forest productivity- An ecological perspective.
20. Ecological assessment of the proposed Airport site in Mizoram.
21. Herpetological inventory in NE region.
22. Planning second home for Sangai in Manipur.
23. Loktak Lake Management with Wetland International in Manipur.
24. An assessment of endemism, rarity of flora of North-eastern region.
25. Turtle fauna assessment in North-east India.
26. Impact of the Forest Fragmentation on the Hoolock gibbon in Assam.
27. Habitat use by the Great Indian Rhinoceros and other sympatric large herbivores in Kaziranga, Assam.
28. Assessment of new additions in the existing areas of KNP – Assam.
29. Edge related changes in species composition in vascular epiphytes in forests of Sessa Orchid Sanctuary, Arunachal Pradesh.
30. Conservation of Hoolock gibbon (Bunopithecus hoolock) in Northeast India.

New Initiatives

To address the issues and concerns related to the biodiversity rich areas in the rainforests in this region, the WII has laid special emphasis in its recently revised research priority matrix to address all the elements of biodiversity at the landscape level using three pronged strategy (Anonymous, 2002). In this new strategy, the priority is to be defined first in the form of selecting landscapes. Within this selected landscape, would be research topics and sites will be determined based on a few major conservation problems. This shall have the potential to make valuable additions to the existing scientific knowledge. The three distinct stages of this strategy would be:

- To undertake landscape level macro studies at the first stage of this strategy, aiming at profiling the land use, the overall status of wildlife Conservation and wellbeing of local people.
- The above first stage shall be followed up by the 2nd Stage of the strategy through quantification of data aiming at benchmarking of the current status of wildlife habitats and abundance of selected flagship/indicator/keystone species. This stage shall also ensure that due attention is also paid at benchmarking the economic status and dependency of neighboring communities on the natural resources.

- The concluding 3rd Stage will relate with selection and prioritization of individual/ group of topics for intensive studies within the selected landscapes to address the all possible issues related with the biological, management and human components of the biodiversity.

  For the purpose of this new landscape approach to address the biodiversity related issues in the region, the Eastern Himalayan Region (covering the entire North-East India) has been identified as New Landscape. Details on the following components of the Region have also been worked out to facilitate actions to be taken during stages 2 and 3 as described above:

- Name and location of the prominent protected areas.
- Name, location and area of the important managed forests
- Name, extent and location of the Important Ecosystems
- Population of the important communities and individual species of high conservation values
- Major threats to the area with special linkages with the development projects, if any.
- Main issues and concerns related to the indigenous/local people
- Listing of prominent animal species for health monitoring
- List of key select topics for undertaking experimental research
- Identified agencies (local institutions, universities, NGO groups, etc.) to be involved for undertaking research activities on different aspects identified and prioritizes as above).

As a part of these new initiatives, the WII has also conducted special meetings with the Chief Wildlife Wardens of the northeastern states during the Annual Research Seminar of the institute during the last couple of years to identify and prioritize the research and training issues for each of those individual states. A proposal was also mooted and agreed upon that each northeastern state must have a Wildlife Research and Training Cell within the forests department to be headed by a senior officer for developing permanent and viable liaising with a similar cell in the WII on matters related to wildlife research and training needs. While four states (Mizoram, Manipur, Tripura and Meghalaya) have already created the Cell, other states are in the process of doing so. The WII has also drafted one Action Plan on Wildlife Research and Training specifically for the northeastern states, which has been circulated to each of the state for detailed discussions and finalization of the identification and prioritization process of specific research and training needs. Most of the states have acted on this draft Action Plan and submitted a list of prioritized research and training issues for future course of action. The Training, Research and Academic Council (TRAC)

and the Governing Body of the WII have also stressed on the needs for initiating and undertaking more and more research and training projects across this region.

Following are the objectives that are identified and included in the draft Action Plan on Wildlife Research and Training for the northeastern states:

1. Developing linkages between WII and the Wildlife Wings of all Northeastern States.
2. Providing technical inputs by WII to the Wildlife Research & Training Cell (WRTC) of the states in prioritization of research activities and helping them in capacity building processes.
3. To help WRTCs in raising funds for research activities.
4. To undertake Joint Research and Training Projects with WRTCs.
5. To involve local researchers, NGOs, Universities, and other Institutions in various Research and Training Programmes.
6. To undertake training programmes for officers at different levels including Training of Trainers (TOT) in various themes of immediate concerns.
7. To actively involve PA managers in research & training projects
8. To document and link use of traditional knowledge with the advanced scientific methods, especially for tackling the issue of shifting cultivation in the region.

(With more than 100 tribal groups in NE, the traditional knowledge system is very rich and need be documented and put to practice as one effective tool for WL conservation)

9. To address the upcoming issue of man–animal conflict with the use of experimental and applied research in usage of various traditional and advanced mitigation measures.
10. To identify major land-use patterns in view of the community ownership of the forests and wilderness area and arrive at best practice guide.
11. To devise and test the applicability and feasibility of Wildlife Protection measures under different conditions.
12. To ensure fair and equitable representation of Wildlife Conservation issues related to NE States in all the in-house Research & Training activities /projects / courses.

In order to achieve the above objectives, the following Action Points are suggested in the draft Action Plan:

1. Creation of a NE India Cell for Research and Training (NICRT) in the WII.

2. Appointment of a Nodal Officer to head the NICRT, besides other staff from within the existing setup.
3. Creation of a Wildlife Research & Training Cell (WRTC) in each NE State.
4. . Appointment of a Nodal Officer for WRTC (at least of DCF rank).
5. To encourage WRTCs to hold series of thematic Workshops for prioritization of the research and training projects related to Wildlife Conservation.
6. The WII may provide technical inputs for undertaking all such research and training inputs.
7. Actions as above can follow a NE level workshop involving all the NE States, concerned NGOs and other Research & Training Organizations involved in the matter of Wildlife conservation.
8. State Forest Departments may seek technical inputs in the form of consultancy from the WII while preparing the research projects and submitting to different National/ International funding agencies to raise funds for Wildlife Research & Training
9. WII to also actively involve as joint partner in various research, training and monitoring projects of mutual interests addressing Wildlife Conservation.
10. The initial focus by WII could be on collection of base line data & thorough surveys, periodic monitoring and resource evaluation of different habitat types.
11. Another important area for the WII could be to prepare different Techniques' Manuals for different major species with funding and man-power support from SFDs
12. Networking with various local Scientific Institutions, Universities and NGOs.
13. Encourage WRTC to engage local researchers in self-run projects covering different research topics.
14. Training component in all the research projects for front line staff as Training of Trainers to maintaining continuity in monitoring even after the project ceases to exist'
15. WRTCs may be encouraged to conduct short thematic training workshops for officers at different levels and WII may provide technical inputs.
16. Wherever possible, the PA managers may be made partners in research, monitoring and training projects being undertaken within their jurisdiction. *This may ensure better quality in the output and better time management.*
17. Special emphasis shall be given in documenting information/data related to propagation /use of medicinal plants.

18. Documentation of traditional methods for maintaining 'Sacred Groves'. Such traditional knowledge and methods may be used in combination with advanced technologies in a given area/ habitat.

19. A thorough assessment on the practice and effects of shifting cultivation vis-à-vis wildlife management.

20. Search for viable alternatives to wean away the faulty land use patterns either for shifting cultivation or management of community controlled areas.

21. An assessment on the role of Autonomous District Councils, various Cooperatives, and Rights and Concessions of various ethnic groups in view of the panchayati Raj Institutions and recent Panchayats (Extension in Scheduled Areas) Act in the NE region.

22. To identify suitable measures and steps to check poaching and encroachments, especially addressing the cultural and traditional needs for subsistence hunting and sports.

23. Possibilities on setting-up of Anti- poaching camps in areas of greater vulnerability to poaching and illicit trade.

24. Feasibility studies on the applicability of participatory approaches (Ecodevelopment, Joint Forest Management, etc) to address issues related to wildlife protection, man-animal conflicts, and faulty land-use patterns.

It is expected that by undertaking special measures and steps as described above, the biodiversity richness of the northeastern region is provided desired protection so that this region, as one of those last few remnants of the rainforests world over, is kept alive and vibrant with the diversity of flora and fauna, much essential for the survival of the humanity in the long run.

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Chapter 19

A REPORT ON THE SURVEY OF RAINFOREST FRAGMENTS IN THE WESTERN GHATS FOR AMPHIBIAN DIVERSITY

Karthikeyan Vasudevan

Introduction

A survey of the rainforest fragments in Kerala was conducted as part of the project titled "Impact of forest fragmentation on the biological diversity of rainforest small mammals and herpetofauna of the Western Ghats mountains, southern India". This project was a USFWS, WII and SACON collaborative project that spanned from 1996 to 2001. The first phase of the project dealt with the identifying the factors that govern diversity in a contiguous rainforest. The rainforest covering ca. 100 sq. Km in Kalakad-Mundanthurai Tiger Reserve (KMTR) was identified as a study site and information was gathered. In the second phase of the project the focus was on quantifying the impacts of rainforest fragmentation on the diversity of herpetofauna and small mammals. The fragmented landscape of Anamalais was chosen as the study site for this phase. In the third phase the project aimed to validate some of the findings that were obtained from the intensive study in the contiguous rainforest study site of KMTR and in the fragments of the Anamalai hills. This involved identifying rainforest fragments in the state of Kerala and sampling them. A report on the number of species documented in the rainforest fragments of Kerala and the two other study sites of KMTR and Anamalais is presented here.

There are about 220 amphibian species documented in the country while the Western Ghats alone has more than 120 species (Daniels, 1992). The amphibian diversity of the Western Ghats are well known for their uniqueness, with more than 80% of them being endemic to the region. Most of the endemic species have their distribution in the rainforests of these mountains. The intensive study on the amphibian diversity documented patterns in loss of diversity due to rainforest fragmentation. However, these findings would gain wider applicability if data were collected again in a different area and then tested for conformity to the patterns observed through the intensive study. The results presented here are from this survey and comparable data from the intensive studies carried out in KMTR and the Anamalai Hills. The conclusions have been made by collating information gathered during the entire study period and do not restrict to the findings from the survey of fragments in Kerala.

Study Area and Methods

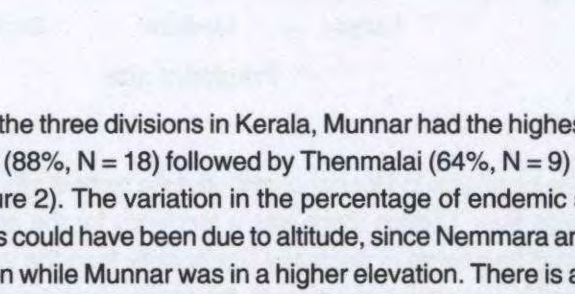
The survey was conducted between February and May 2001 in Nemmara, Munnar and Thenmalai forest divisions of Kerala. These forest divisions have remnant rainforest fragments in a landscape, which has been modified from rainforest to plantation crops such as rubber, coffee, cardamom and tea. The choice of the rainforest fragment for sampling was limited due to the nature of the matrix and logistic constraints. During the intensive study in the Anamalais 14 fragments belonging to three size classes namely, very large (> 501 ha), large (151-500 ha), medium (11-150 ha) and small (< 10 ha) were sampled. In the three forest divisions of Kerala 11 fragments in large and medium size classes were sampled.

The survey employed quadrat search to enumerate forest floor amphibians (refer to Vasudevan et al. 2001 for details). The inventory of species in rainforest fragments also included the opportunistic sightings. Caecilians have been excluded in the comparison since they were not targeted in the sampling and all the records from the intensive study either came from road kills or opportunistic sightings.

Results and Discussion

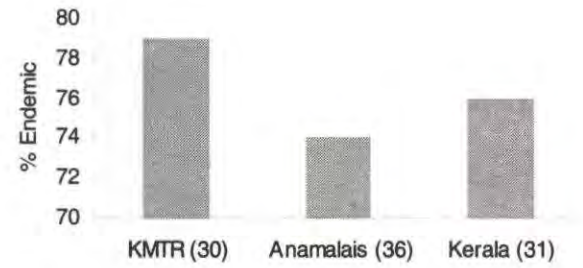
The survey documented 31 species of amphibians of which 24 are endemic to the Western Ghats. Among these species, six have not been identified (Appendix). At least one "new species" of *Bufo* has been recorded. In the percentage of endemic species the amphibian community in the rainforest fragments of Kerala was comparable to that of Anamalais (76%, N = 36) and the contiguous rainforest in Kalakad-Mundanthruai Tiger Reserve (79%, N =30; Figure 1). Although individual fragments have low species richness and proportion of endemic species (mean = 8.6 & 0.55), the fragments together have species richness and proportion of endemics (mean = 21 & 0.75) comparable to the contiguous rainforest. In terms of area the contiguous rainforests of KMTR has more than three times the extent of rainforest than the Anamalais, despite this the fragments provide refuge for a sizeable number of endemic amphibians.

Figure 1. Percentage of endemic amphibian species recorded in different study areas during the project. The total number of species recorded is given in parenthesis.



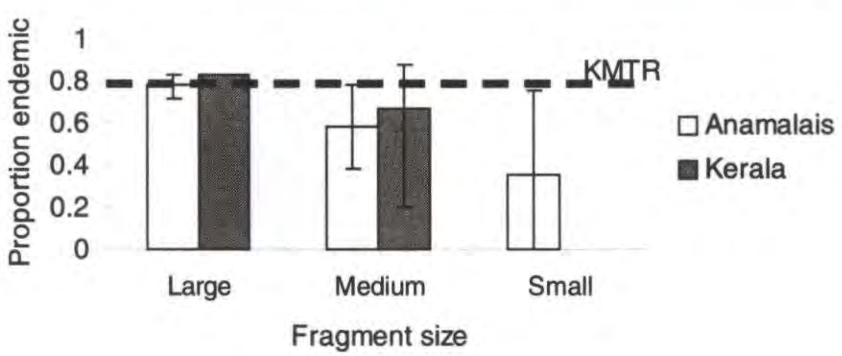
Among the three divisions in Kerala, Munnar had the highest percentage of endemic species (88%, N = 18) followed by Thenmalai (64%, N = 9) and Nemmara (60%, N = 15; Figure 2). The variation in the percentage of endemic species among the three divisions could have been due to altitude, since Nemmara and Themalai were in lower elevation while Munnar was in a higher elevation. There is a tendency for endemicity in amphibians to be highest between 800 and 1400 m msl (Daniels, 1992).

Figure 2. Percentage of endemic amphibian species recorded in rainforest fragments in three divisions in Kerala between February and May 2001. The total number of species recorded is given in parenthesis.



A comparison of the data from fragments of different size classes indicates that there is a decline in the proportion of endemic species with decreasing fragments area in the fragments that were sampled in Kerala, as in the case of fragments in the Anamalai Hills (Figure 3). The large fragments had proportion of endemic species comparable to that of the contiguous rainforests of KMTR (Figure 3).

Figure 3. Proportion of endemic amphibian species in contiguous rainforest of KMTR, fragments of the Anamalais and Kerala. The histograms indicate the mean or single values for the proportion, and the error bars the maximum and minimum values wherever available.



The fragments in Munnar contributed the highest proportion of endemic species in the large size. Though there was a tendency for the proportion of endemic species in small fragments to decrease significantly from the values obtained for the large and contiguous rainforest samples, the range of values obtained indicates that size of the fragment alone did not contribute to the decline in diversity of amphibians. Some medium sized and small fragments that were less disturbed and were relatively intact had greater proportion of endemic amphibian species. The fragments in Munnar were

geographically closest to the Anamalais than the fragments in other divisions. The elevation range of the forest fragments in the large size category was also comparable for the Anamalais and Munnar. This is reflected in the similarity in the amphibian species between these two areas.

Conclusions

1. In the southern Western Ghats, when four segments of 2°N latitude were compared for the extent of amphibian species overlap, it was observed that there was an overlap of less than 60% of the species between any of these segments (re-analyzed from Daniels, 1992). Our intensive study has documented a similar pattern of turnover of diversity of amphibians. Many of the rainforest fragments such as those in Munnar hold several endemic species of amphibians and have important conservation value. More so, because these endemic species may be specific to a drainage and would not be shared with those of other rainforest areas in the Western Ghats.

2. Size of the fragments alone does not contribute to the reduction in the endemic amphibians, the quality of the fragment plays an important role in regulating the diversity of amphibians in the fragmented landscape.

3. The general pattern of loss of endemic species with increasing intensity of fragmentation of the rainforest habitat may hold true for the southern Western Ghats.

4. In view of extent of rainforest fragmentation of the Western Ghats, it should be considered a priority to inventory the amphibian taxa and document the so far undescribed species surviving in the remnant rainforest fragments.

5. The turn over of diversity of amphibians across drainages and hill ranges documented through this study point at the inadequacy in the PAs in different drainages along the Western Ghats, if the amphibian diversity has to be conserved.

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Appendix

List of amphibian species recorded in different fragments in three forest divisions of Kerala, includes unidentified species. The size of the fragment is mentioned in parenthesis. The survey was carried out between February and May 2001.

Munnar Division:

NAYAMAKAD (*Medium*)

Micrixalus fuscus
Indirana leptodactyla
Nyctibatrachus sp
Nyctibatrachus deccanensis
Polypedates pleurostictus
Polypedates sp
Philautus sp1
Philautus sp2
Philautus leucorhinus

VAGAVURRAI (*Medium*)

Limnonectes nilagirica
Micrixalus sp
Micrixalus silvaticus
Indirana beddomi
Indirana leptodactyla
Philautus sp
Philautus temporalis
Philautus pulcherrimus
Polypedates sp

THENMALAI (*Medium*)

Micrixalus silvaticus
Indirana leptodactyla
Philautus konalarensis
Philautus leucorhinus
Philautus pulcherrimus

KADALAAR RIDGE (*Medium*)

Micrixalus silvaticus
Micrixalus sp
Indirana leptodactyla
Philautus konalarensis
Philautus leucorhinus
Philautus pulcherrimus

KADALAAR RIVER (*Medium*)

Micrixalus fuscus
Indirana leptodactyla
Indirana beddomi
Nyctibatrachus sp
Nyctibatrachus decannensis
Polypedates sp
Philautus sp1
Philautus sp2
Philautus charius
Philautus leucorhinus
Bufo sp
Bufo melanostictus

KFDC KADALAAR (*Large*)

Limnonectes nilagirica
Limnonectes sp
Micrixalus fuscus
Micrixalus sp
Micrixalus silvaticus
Indirana leptodactyla
Indirana beddomi
Indirana phyrnoderma

Indirana brachytarsus
Rana temporalis
Nyctibatrachus decannensis
Ncytibatrachus sp
Bufo sp
Bufo melanostictus
Polypedates sp
Philautus sp
Philautus pulcherrimus
Philautus charius

Nemmara Division:

KAIKATI AVT (*Medium*)

Bufo melanostictus
Philautus temporalis
Rana aurantiaca
Linonectes brevipalmata
Euphylictis cyanophylictis

KADALAAR RIVER (*Medium*)

Micrixalus fuscus
Indirana leptodactyla
Indirana beddomi
Nyctibatrachus sp
Nyctibatrachus decannensis
Polypedates sp
Philautus sp1
Philautus sp2
Philautus charius
Philautus leucorhinus
Bufo sp
Bufo melanostictus

KFDC KADALAAR (*Large*)

Limnonectes nilagirica
Limnonectes sp
Micrixalus fuscus
Micrixalus sp
Micrixalus silvaticus
Indirana leptodactyla
Indirana beddomi
Indirana phyrnoderma
Indirana brachytarsus
Rana temporalis
Nyctibatrachus decannensis
Ncytibatrachus sp
Bufo sp
Bufo melanostictus
Polypedates sp
Philautus sp
Philautus pulcherrimus
Philautus charius

Nemmara Division:

KAIKATI AVT (*Medium*)
Bufo melanostictus
Philautus temporalis
Rana aurantiaca
Linonectes brevipalmata
Euphylictis cyanophylictis

KAIKATI OVF (*Medium*)

Bufo melanostictus
Philautus pulcherrimus
Philautus leucorhinus
Rana aurantiaca

Nyctibatrachus sp
Euphylictis cyanophylictis

TAMBOORAN KADU (*Medium)*

Micrixalus gadgili
Micrixalus fuscus
Indirana brachytarsus
Nyctibatrachus sp
Rana temporalis
Indirana beddomi
Bufo melanostictus
Philautus pulcherrimus

Thenmala Division:

PALARUVI (*Medium)*
Limnonectes brevipalmata
Indirana semiplamata
Micrixalus fuscus
Rhacophorus malabaricus
Philautus pucherrimus
Philautus leucorhinus
Philautus temporalis

***PRIYA ESTATE (*Medium)**

Limnonectes brevipalmata
Indirana semiplamata
Micrixalus fuscus
Micrixalus nudis
Rhacophorus malabaricus
Philautus pucherrimus
Philautus leucorhinus
Philautus temporalis
Bufo melanostictus

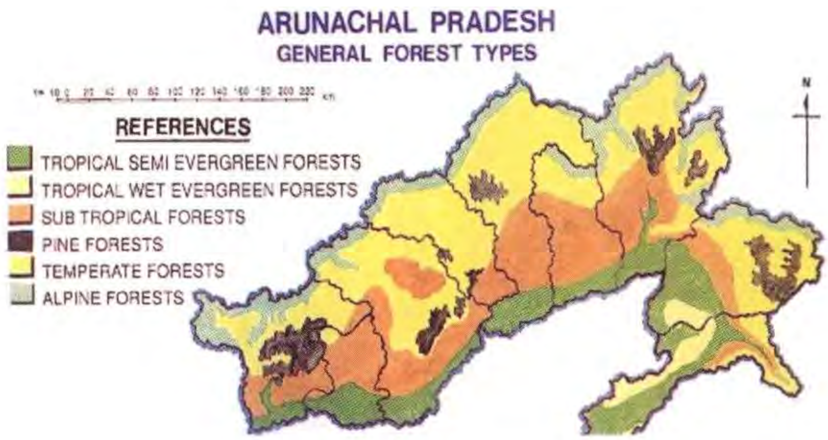
Chapter 20

CONSERVATION OF TROPICAL RAIN FORESTS IN ARUNACHAL PRADESH

D.N. Singh

Introduction

The Arunachal Pradesh is situated between 260 28' N & 290 30' N latitudes and 910 30' E & 970 30' E longitudes. It covers a geographical area of 83,743 sq. km. It is the largest state in the northeastern part of India among seven sisters. The state is predominantly hilly and mountainous. It is flanked by China in the north and northeast (1,080 Km) separated by McMohan line, by Bhutan (160 Km) in west, by and Myanmar(440Km) in east, and in south by the Indian states of Assam and Nagaland. It is predominantly a tribal state consisting of 82 major tribes and sub-tribes of Indo-Mongoloid and Mongoloid lineage. (Singh, 1999). It has 16 districts. Most of the land area of the state is under tribal ownership which is managed under their customary practices. In Arunachal Pradesh the Tropical Wet Evergreen Forests (Rain Forests) occurs in around 1000 sq.km. area in the Tirap, Changlang and Lohit (Namsai sub-division) districts.(Figure I)



It is located between 270 N & 280 N Latitude and 940 30' E to 950 15' E Longitude. This tropical rain forest patch exists 270 N of equator in sub-tropical belt due to significant variations in climatic elements. The climatic conditions are closely associated with the atmospheric conditions of the Indian sub-continent which is controlled by

(a) prevalence of atmospheric conditions in the Indian Ocean where South-West monsoon is developed and pushed towards the Tropical Zone by the cross-equatorial jet-stream of the Indian Ocean, and

(b) topographic features of the Great Himalayan ranges of the East and 'the Himalayan loops' situated on Indo-Tibetan and Indo-Burmese borders of the East (Hills of Barail, Naga, Patkai-Bum and Mishmi) specify the causes of seasonal as well as areal variation in micro-climatic elements in Arunachal Pradesh. The surface winds in this belt are governed by high atmospheric pressure on the Indian Ocean and

low pressure in the areas of the Greater Himalayas and very low pressure in the Western parts of the sub-continent during the summer season. This, cross equatorial jet stream moves towards the foot-hill areas of the Arunachal Himalayas and pushes the sub-tropical jet stream northwards. As a result, climatological front shifts in those areas of the state during summer. (Singh, 1999). It creates tropical characteristics in the sub-tropical belt.

These rain forests are restricted along the south bank of the Brahmaputra river. It is termed as South Bank Tropical Wet Evergreen Dipterocarpus Forest (Champion,1968). Its altitude varies between 150 mts to 600 mts. The mean temperature ranges between 220 C to 360 C in summer and 100 C to 250 C in winter. The rainfall starts with pre-monsoon rains in March. It is followed by the onset of Monsoon in May to its withdrawal during September (3/4th rainfall occurs during this period). The retreating monsoon and North East Monsoon also causes some rains in between. The total rainfall in this belt is in the range of 2500 mm to 3500 mm. There virtually exists no dry month in this belt.

This forest type is characterized by its unique structure and composition with important commercial timber species like Dipterocarpus macrocarpus (Hollong), Shorea assamica (Mekai), Terminalia myriocarpa (Holock), Mesua ferrea (Nahor), Altingia excelsa, Artocarpus chaplasha, Michelia spp. Amoora wallichi, Tetrameles nudiflora, Ailanthes grandis etc. The forest is rich in orchids (with around 132 spp) and other epiphytes, ferns, climbers. (Anon., 1993)

From the forestry management point of view, the entire rain forest area is under the territorial jurisdictions of Deomali Forest Division, Nampong Forest Division and Namsai Forest Division in the south and southeastern parts of the state. The parts of Tirap, Changlang and Lohit district covering the tropical rain forest area is inhabited by the tribal population mentioned in the Table I.

TRIBES	POPULATION (1991)
Deuris	4,900
Khamti	8,339
Mishmi	3,133 (only Wakro Circle)
Singpho	2,978
Tangsa	26,016

The tropical rain forests of Arunachal Pradesh have been notified for scientific management on the basis of the silvicultural practices as various types of Reserved Forests since 1936 when first reserved forest was notified at Namsai. The reserved forests which have wet evergreen forests types in its floral composition are listed in the Table II.

Sl No	District	Division	Name of the Reserved Forest	Area (in sq.km.)	Year of creation
1	Lohit	Namsai	Lohit	51.12	1978
			Manabhum	148.98	1937
			Namsai	23.73	1936
			Noa-Dehing	13.42	1937
			Tengapani	373.83	1965
			Turung	167.69	1964
2	Changlang	Nampong	Diyun	173.20	1970
			Diyun ARF	119.13	1982
			Honkap	73.39	1965
			Khathang	17.53	1962
			Koripani	6.06	1962
			Miao	125.82	1962
			Namchik	49.82	1962
			Namdang	42.77	1976
			Namgoi	18.30	1976
			Namphai ARF	14.05	1982
			Namphuk	57.20	1962
			Pangsau	69.12	1970
			Rima	67.64	1976
3	Tirap	Deomali	Borduria VRF	38.54	1962
			Chattong VRF	3.03	1994
			Chopnu VRF	5.14	1994
			Mopaya VRF	26.00	1994
			Namsang VRF	108.88	1962
			Rujen VRF	20.28	1992
			Russa-Chopsa VRF	7.50	1987

Threats to Rainforest

The main threats to the conservation of tropical rain forests in the state are:

Human Population Growth: The Tirap, Changlang and Lohit districts have seen tremendous growth of human population over the years compared to other parts of the state and the country. (Table III).

Year	1961*	1971	1981	1991	2001
Population of the region	75,071	1,24,149	1,67,569	2,42,273	3,05,569
Decadal Growth Rate of the region		65.37	34.97	44.58	26.13
Decadal Growth Rate of India	21.64	24.80	24.66	23.86	21.34
Decadal Growth Rate of Arunachal Pradesh	NA	38.91	35.15	36.83	26.21

* In Arunachal Pradesh census was conducted for the first time in 1961.

Coupled with this is the large scale migration of people from high hills to the valley. It is the valley which has got largest concentration of population compared to hills. The tropical rain forest is concentrated in the valleys and adjacent hills. The people prefer to settle in the valley and use the nearby hills and valley lands for their agricultural and

horticultural uses. All these activities are a potent threat to the future of rain forests. The tribal people of the region are backward and their quality of life needs to be improved to bring them in the national mainstream. However, a judicious balance needs to be maintained between developmental needs and environmental considerations for the benefit of one and all. The excessive growth of population is responsible for all the problems of encroachment and damages to the flora and fauna by biotic pressures.

Shifting Cultivation: The shifting (jhum) cultivation is practiced in the Tirap and the Changlang districts alongwith other parts of the state. It is practiced along the slopes in the valleys. The cycle of shifting cultivation was 3 years in the tropical Wet Evergreen Forests (Assam Valley Tropical Wet-Evergreen Forest) of the Tirap and the Changlang district compared to average of 6 to 10 years in other parts of the state. (Anon.1982). It is estimated that 54,000 families practice shifting cultivation in the state (Anon., 1992) over 0.23 million ha (Anon., 1999). In the past, when the cycle of shifting cultivation was long and the density of population low, the ecological balance was not much disturbed. However, it has now come down to 2 to 3 years. Steep slopes and the areas unfit for agriculture have been brought under cultivation. The land considered fallow due to steepness of the slope or porosity of the soil is now put to use because of population pressure. It is responsible for reduction in the area of the rain forests and is causing immense damage to the forests.

Mining: The tropical rain forests of the Arunachal Pradesh is very rich in deposit of minerals like coal & petroleum. The coal is available in the Namchik-Namphuk Belt. Its reserve is estimated to be 84.23 million tonnes. At present open cast mining is under way at a small scale. However, the economic necessity of the backward state has compelled it to increase the mining to augment its revenue. The state is exploring all avenues to increase its coal production. For this purpose it is seeking help from the private sector on a large scale. The Crude Oil & Natural Gas reserves are available in the Kumchai, Diyun, Kharsang and Nampong belt. It is being explored and exploited at a large scale by the public sector as well as private sector agencies. Although the government grants mining leases over a small area but the damage is caused over a much wider area by the private sector to maximize their return. This is a major threat to future of the rich forests.

Wood based Industries: The tropical rain forest is endowed with Dipterocarpus macrocaups (Hollong) and Shorea assamica (Mekai). These species are in great demand by the plywood and veneer industries for use as face in the manufacturing of the plywood. These species are the main reasons for location of large numbers of wood based industries, particularly, plywood and veneer units in this region. The ownership (licence) of these industries is in the name of the local influential person. However, the financial investments and the operation of the industries are in the hands of the outsiders, the people from the north India. Thus, the industries are operated with sole motive of maximizing profit in the least possible time. As such all possible

foul plays are resorted to by the operators of these industries. The raw material is from the forests and the brunt of the reckless and ruthless operation is ultimately borne by the forests in terms of large scale legal and illegal cutting of timber. The result is the irreparable damage to the ecologically sensitive rain forests. The above fact is corroborated by the seizure of huge illegal timbers in these belts of the rain forests in 1997 as per the orders of the Supreme Court of India.

Tea cultivation: Tea is the most important non-food crop of the North Eastern region. Assam and Tripura are the largest producers of the tea in the region and they accounts for more than 54% of the total tea produced in the country. Tea cultivation in Arunachal is of recent origin. Vast tracts of forested hill slopes having community ownership of the land and favourable climatic conditions present immense potential for tea in the state. Darjeeling variety of tea is found to grow well in the hill slopes. The tea gardens set up in the state forest corporation and other private parties have been a success. The tea is planted in the virgin areas with scope for producing organic tea which has excellent market and high profit margins. Moreover, now the concept of growing tea in small holdings has come up which was unheard of until 1975. The average size of such holdings is less than 1 hectare. Large numbers of private tea processing factories have come up in the region. They process the green leaf supplied by small growers. The tea gardens have seen a phenomenal growth in the state after the restrictions imposed on the timber operation by the Supreme Court of India in 1996. The subsidy, easy loans, setting up of the Tea Development Board by the state government are some other causes helping in the large scale growth of the tea industry in the state. Large areas of the rain forest have been cleared in the recent years to establish tea gardens, particularly in Namsai, Chowkham, Diyun, Bordumsa, Miao, Jairampur and Deomali areas.

Developmental Activities: The Tirap and Changlang are the most backward districts of the state. The planners and leaders of these remote and backward districts are trying hard to develop it to accelerate the pace of economic development. Consequently, development of social and economic infrastructure in the towns and villages has been taken up on a large scale. Such developmental projects in these hilly areas have been taken up without adequate environmental considerations. The result is deforestation, soil erosion and damage to the ecological balance.

Insurgency: The rain forest belt of the Lohit, Tirap and Changlang districts of the state is badly affected by the insurgency. It has its impact on the overall protection of the forests by the forest personnel. Sanctioned posts are vacant for years. The staffs posted are afraid to venture inside the forests for patrol duty. As a result of this the entire area is practically unguarded and unprotected putting a big question mark on the very survival of this fragile ecosystem.

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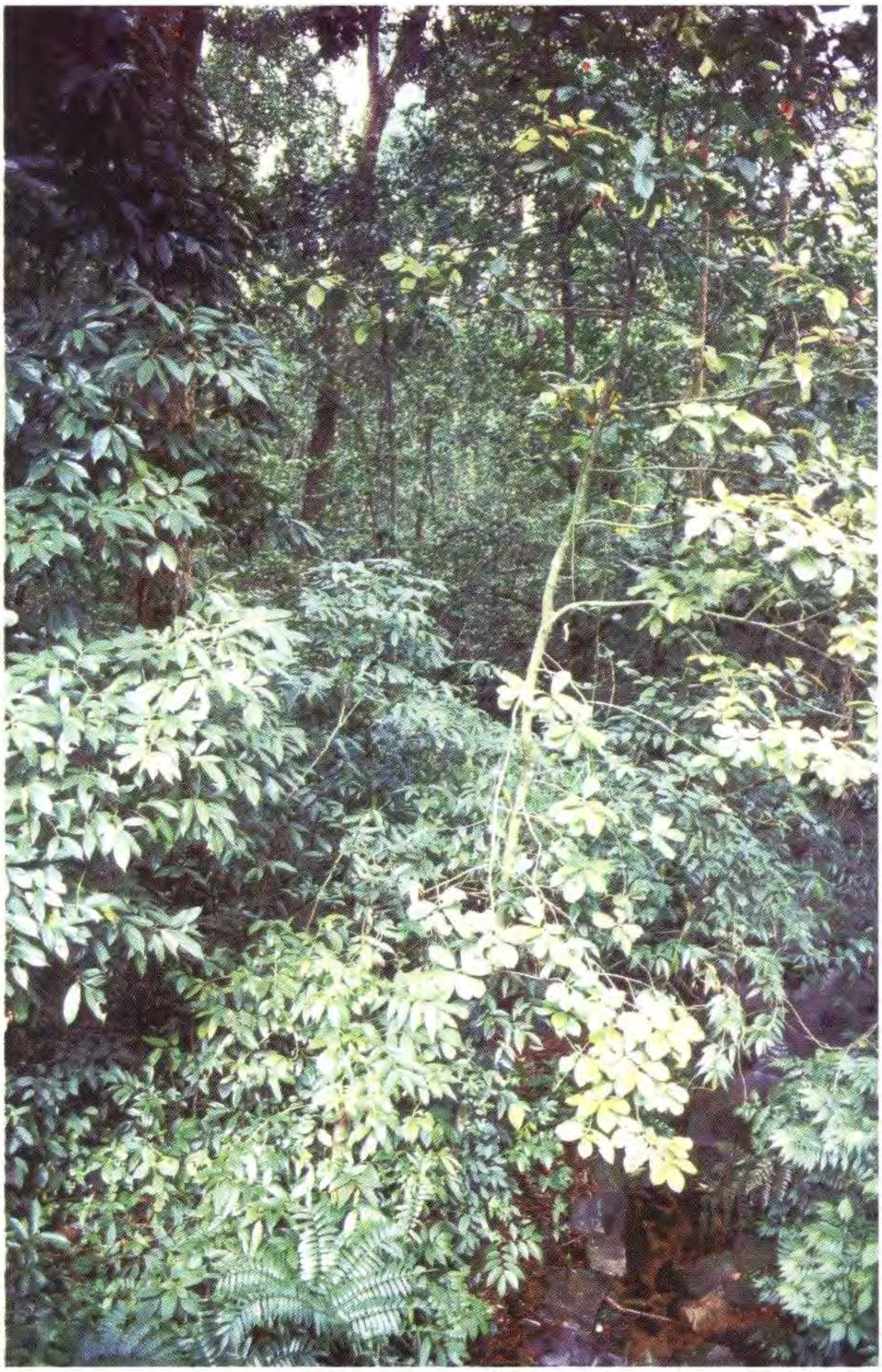
Plate 7



Forest Interior in Annamalai : S.U. Saravana Kumar

Chapter 21

Selected Bibliography on Conservation of Rainforests in India

M.S. Rana and Shashi Uniyal

Introduction

The present information on Conservation of Rainforests is widely scattered in India. In such a situation, access to appropriate and relevant literature by the researchers becomes both critical and difficult. This compilation is the first of its kind to collate the existing published information on *conservation of rainforests in India* contains 810 references that are largely in English language. The bibliography covers almost 132 years (Between 1872 to 2003).

The main secondary sources consulted for this compilation include the following databases :-

a. International Database
   Wildlife and ecology studies world-wide- CD-ROM (period 1935-2003)
b. WII Library and Documentation Center in-house database
   i. Reprint database
   ii. Book database
   iii. WILD (Indexing and Abstracting database of Indian Wildlife)
   iv. Mammal database

To facilitate easy access to the citations we have provided four indices;

a) The **Author index**,
b) The **Subject index**,
c) The **Species index** and
d) The **Publication year** index.

We have categorized the bibliography on the scope of the article and placed them under 17 broad subjects headings. Among these Vegetation followed by mammals dominate the database.

(Table 1 : Subject Distribution)

Subject	**No. of References**
VEGETATION	218
MAMMALS	203
BIRDS	123
CONSERVATION	110
ECOLOGY	96
DISTRIBUTION	79
BEHAVIOUR	72
AMPHIBIANS	62
REPTILES	43

STATUS REPORT	43
INSECTS	35
GENERAL	31
LAND USE	29
TAXONOMY	17
TECHNIQUES/TOOLS	11
FISHES	7
MOLLUSCS	1

Further analysis of database shows that the species like Lion-tailed Macaque {*Macaca silenus*}, Hoolock Gibbon {*Bunopitheus* (Hylobates) *hoolock*} and Nilgiri Langur {*Trachypithecus johnii*} have been mostly studied in rain forest in India.

The trends in the chronological development of literature has been shown in Table 2. The number of publications in a year ranged from 0 – 68 with the year 2001 recording the maximum publications (68).

(Table 2 : Chronological Development of Literature)

Period	**No. of References**
1872-1899	9
1902-1929	10
1930-1940	16
1941-1950	10
1951-1960	17
1961-1970	35
1971-1980	45
1981-1990	197
1991-2000	349
2001-2003	100
undated	16
in press	6

Over 602 authors have been indexed in the present database and their contribution to increasing our understanding of the rain forests in India measured in-term of number of publication ranged from 1-38. The leading authors who contributed ≥ 20 articles were: Ajith Kumar, P.S.Ramakrishnan, P.Davidar, T.Ganesh, J.P.Pascal and T.R.S.Raman. Of 810 articles, 415 articles were found to be contributed in collaboration.

For the convenience of the user, this bibliography is also available in database form at the Wildlife Institute of India, Library and Documentation Centre. It is hoped that providing information both in traditional printed form as well as through machine readable

database will be very useful and act as a ready reference to both professional and amateur wildlife ecologists and protected area managers, interested in the rainforests conservation in India. We would also like to add that this database is not complete. While, all possible efforts have been made to cite the references as accurately as possible, it is probable that some mistakes have remained, largely owing to the compilation of the majority of references from secondary sources. We would be grateful if such mistakes are brought to our notice for correction and continuous upgradation of this database.

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